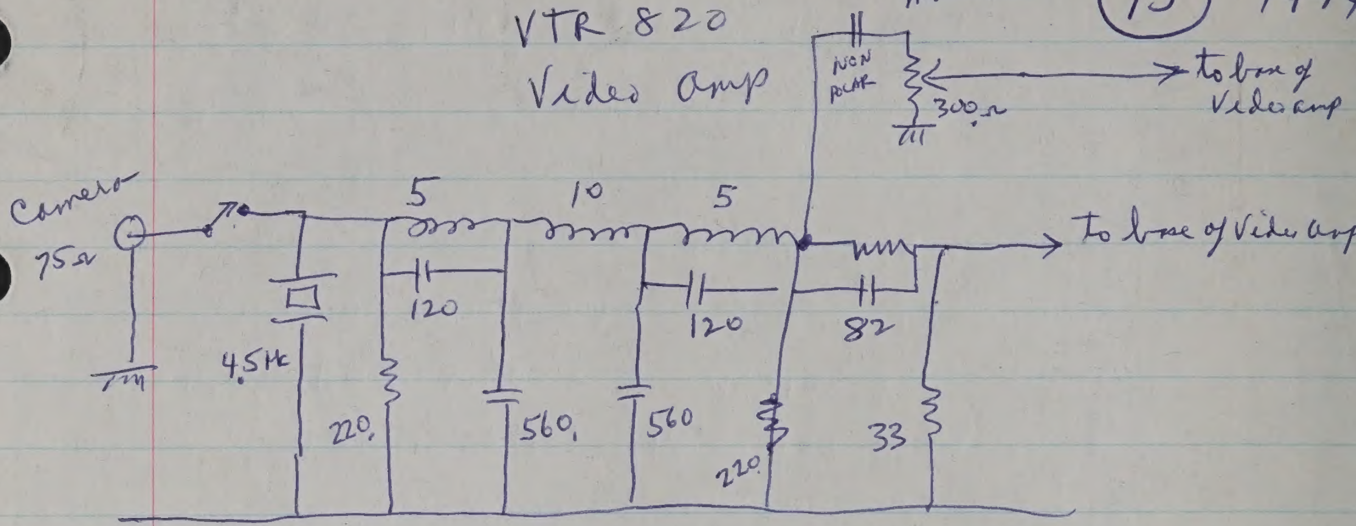
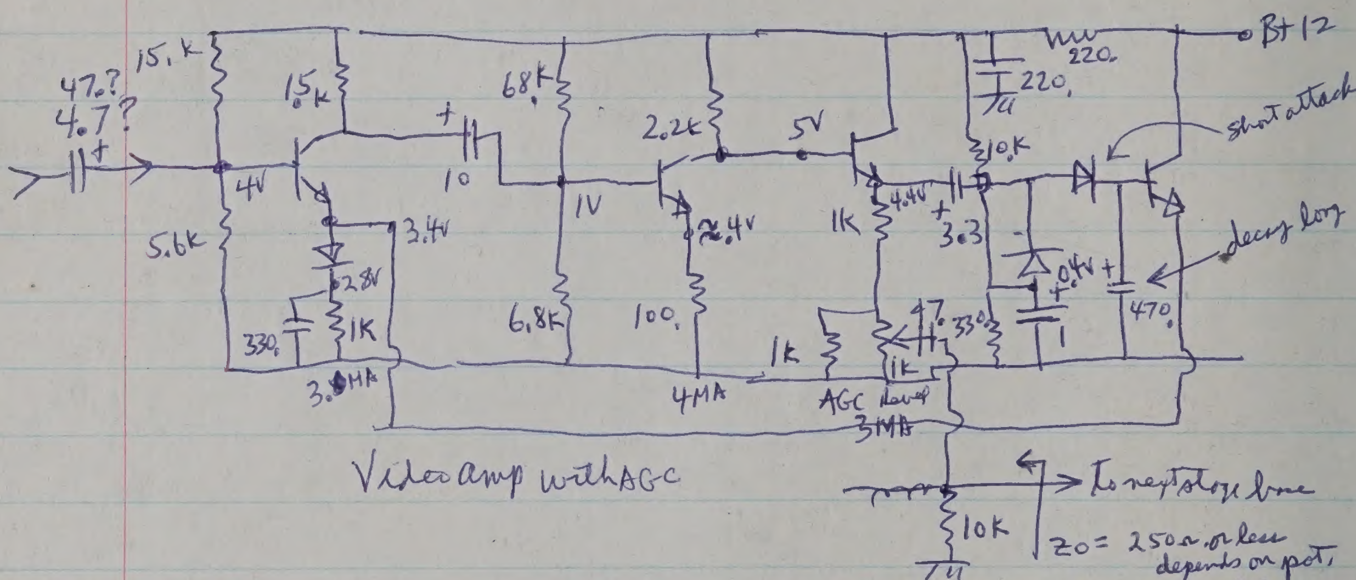
→ FILE Hammarlund FM(?)
(X with automatic level Control)

75 1974

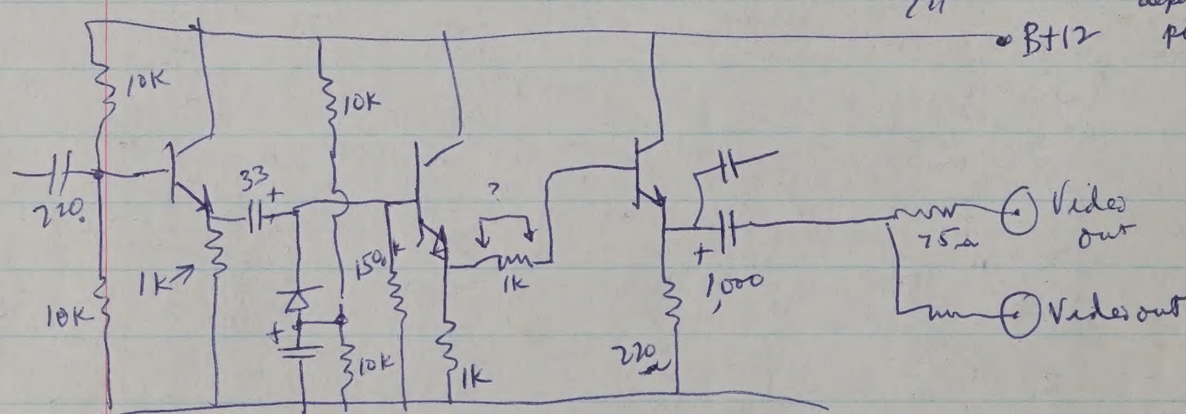
VTR 820
Video Amp



low-pass filter



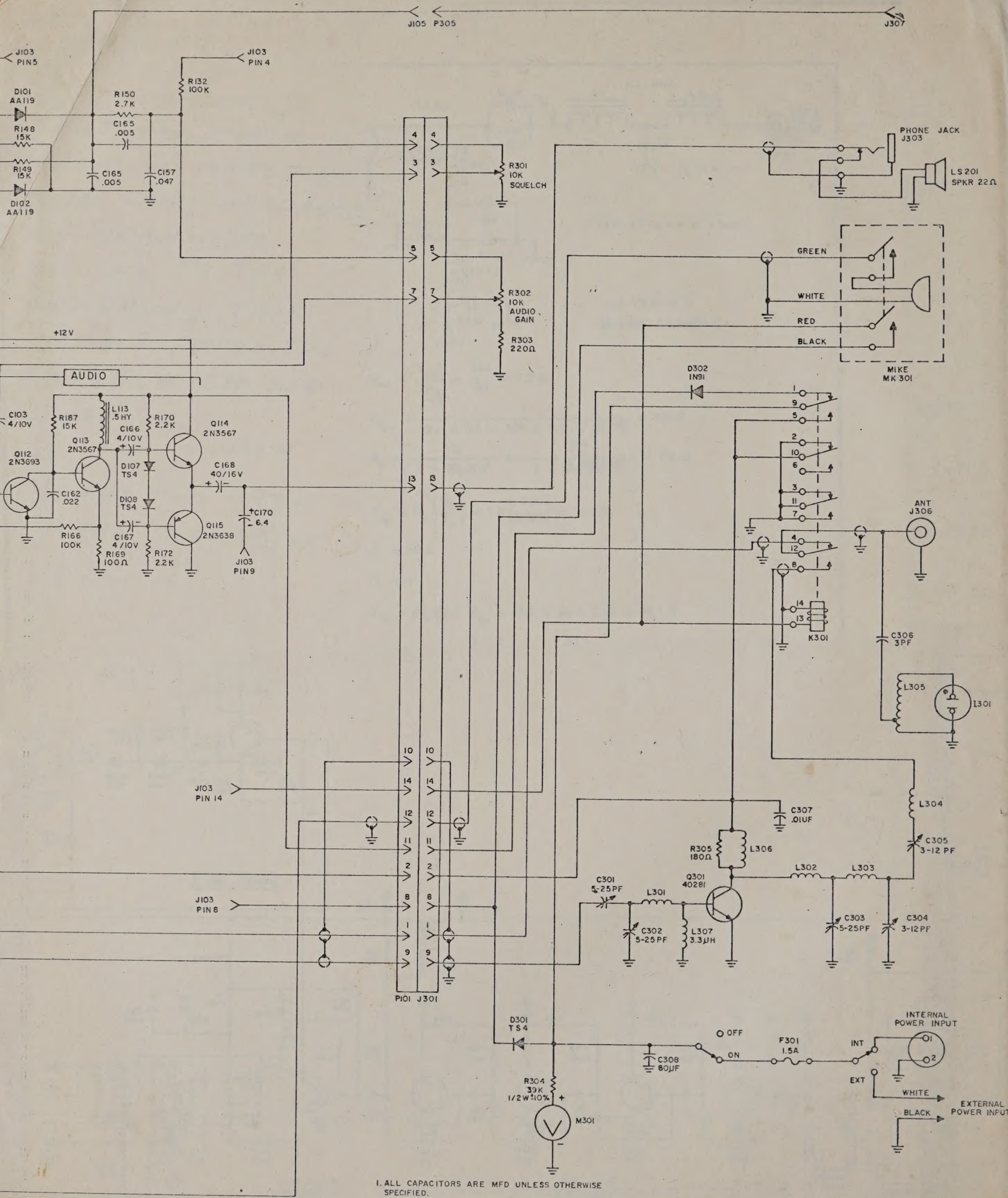
Video amp with AGC



CLAMP

VIDEO output stages V gain less than 1, Reduced to ½ by 75 Ω series output resistor

75



1. ALL CAPACITORS ARE MFD UNLESS OTHERWISE SPECIFIED.
2. ALL RESISTORS ARE 1/4 WATT±10% UNLESS OTHERWISE SPECIFIED.

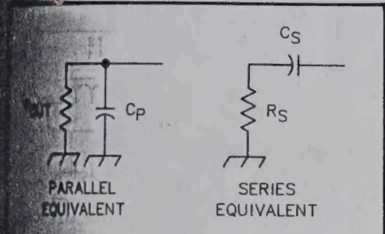
FM1

EVEREST!

YOU INDICATED THAT YOU HAD A PROBLEM MATCHING THE LOW IMPEDANCE OF TRANSISTOR FINALS TO THE ANTENNA. THIS SEEMS TO DO THE TRICK WITH FEW PARTS.

DON.

PAGE 11-11 1994 ARRL HANDBOOK



$$R_S = \frac{R_{OUT}}{1 + (R_{OUT}/X_P)^2}$$

$$X_S = R_S \left(\frac{R_{OUT}}{X_P}\right)$$

Fig 18 — Parallel and series equivalent circuits and the formulas used for conversion.

ohm collector of Q1 and the 5-ohm base of Q2. The shortcoming of this technique is the lack of selectivity between stages, but the advantage is in the broadband characteristic of the coupling system. The phasing dots on the diagram near T1 and T2 indicate the correct electrical relationship of the transformer windings.

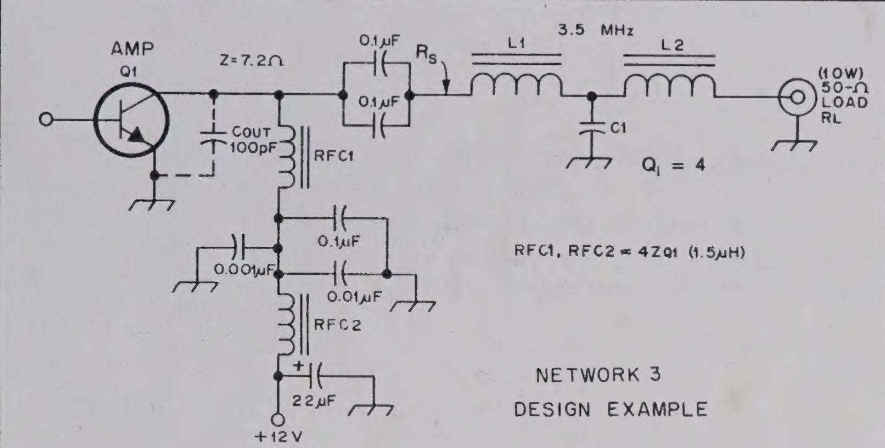
Network Equations

The three networks shown in Figs 15, 16 and 17 will provide practical solutions to many of the impedance-matching problems encountered by amateurs. In each of the figures it is assumed that the output impedance being matched is lower than the input impedance of the following stage. If this is not the case, the network (the circuit elements between the points marked A and B) can be turned around to provide the correct transformation.

Normally, the output impedance of a transistor is given as a resistance in parallel with a capacitance, C_{out}. To use the design equations for these three networks, the output impedance must first be converted from the parallel form (R_{out} and C_{out}) to the equivalent series form (R_s and C_s). These equivalent circuits and the equations for conversion are given in Fig 18. Often the output capacitance is small enough that it may be neglected; the resulting error is compensated for by using variable components in the network.

The low-pass T network (Fig 17) has the advantage of matching a wide range of impedances with practical component values. Some designers feel that of the various networks used in solid-state work, the T network is best in terms of collector efficiency. The harmonic suppression afforded by the T network varies with the transformation ratio and the total Q of the network. For stages feeding an antenna, additional harmonic suppression will normally be needed. This is also true for networks 1 and 2. These three networks are covered in detail in *Motorola Application Note AN-267*. Another excellent paper on the subject was written by Becciolini, *Motorola Application Note AN-721*.

The equations for networks 1, 2 and 3 were taken from AN-267. That paper contains computer solutions to these networks and others, with tabular information for various values of Q and source impedances. A fixed load value of 50 ohms is the base for the tabular data.



$$R_{out} \approx \frac{V_{CC}^2}{2P_O} = \frac{144}{20} = 7.2\ \Omega$$

$$X_{C_{out}} = \frac{1}{(2\pi \times 3.5 \times 10^6 \times 100 \times 10^{-12})} = 454.7$$

$$R_S = \frac{R_P}{1 + (R_P/X_P)^2} = \frac{7.2}{1 + (7.2/454.7)^2} = 7.2\ \Omega$$

$$X_{C_S} = R_S\left(\frac{R_P}{X_P}\right) = 7.0\left(\frac{7.2}{454.7}\right) = 0.11\ \Omega$$

$$R_L = 50\ \Omega$$

$$Q_l = 4$$

$$X_{L1} = (R_S Q_l) + X_{C_S} = (7.0 \times 4) + 0.11 = 28.1\ \Omega$$

$$\therefore L1(\mu H) = \frac{X_{L1}}{2\pi f(MHz)} = \frac{28.1}{2\pi \times 3.5} = 1.28\ \mu H$$

$$R_V = R_S(1 + Q_l^2) = 7.2\,(1 + 4^2) = 122.4$$

$$Q_L = \sqrt{\left(\frac{R_V}{R_L}\right) - 1} = \sqrt{\left(\frac{122.4}{50}\right) - 1} = 1.2 \quad \text{(Total Q = 4 + 1.2 = 5.2)}$$

$$X_{L2} = R_L Q_L = 50 \times 1.2 = 60\ \Omega$$

$$\therefore L2(\mu H) = \frac{X_{L2}}{2\pi f(MHz)} = \frac{60}{2\pi \times 3.5} = 2.73\ \mu H$$

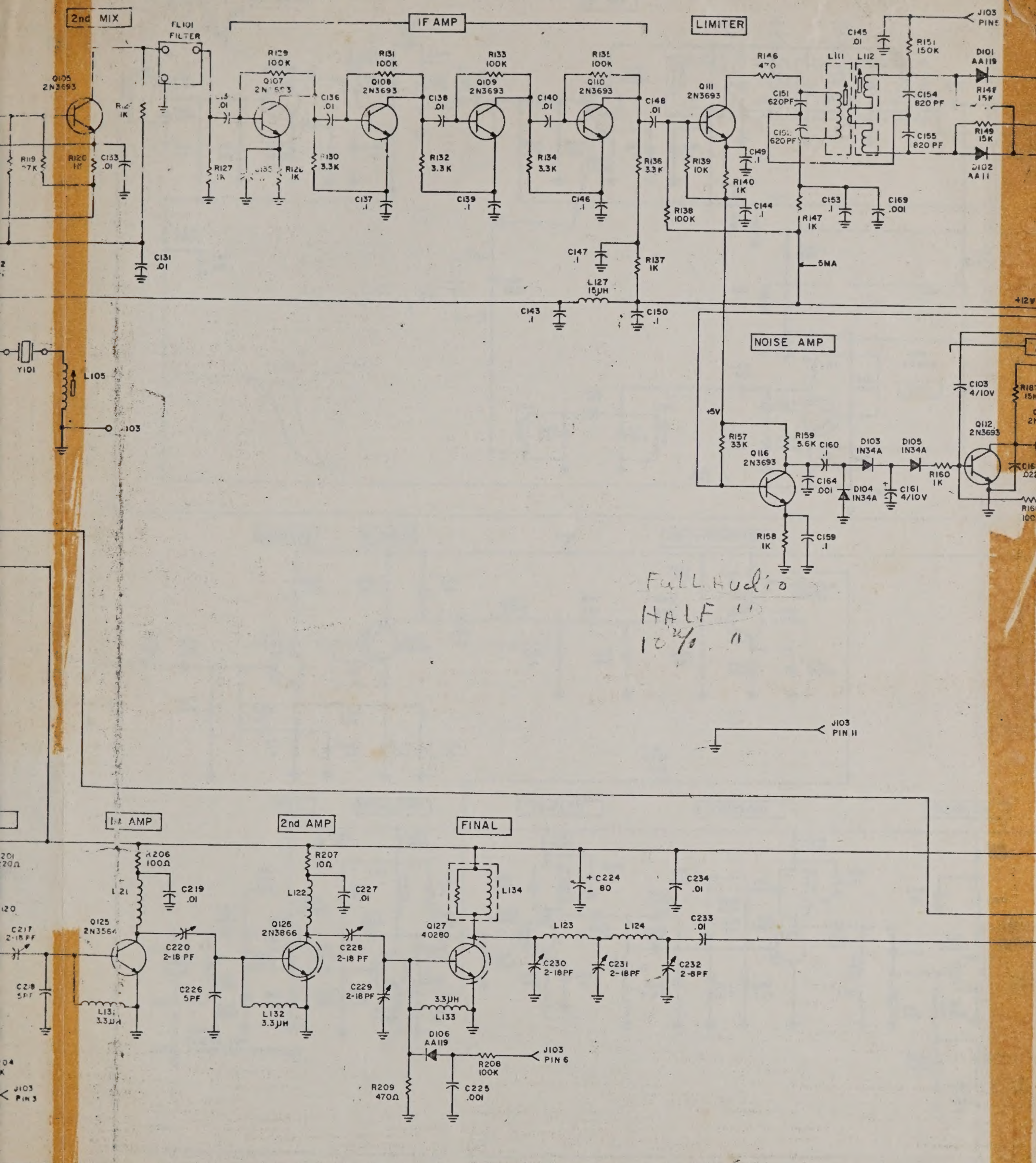
$$X_{C1} = \frac{R_V}{(Q_l + Q_L)} = \frac{122.4}{(4 + 1.2)} = 23.5\ \Omega$$

$$\therefore C1(\mu F) = \frac{1}{2\pi f\, X_{C1}} = \frac{1}{2\pi \times 3.5 \times 23.5} = 0.0019\ \mu F$$

Fig 19 — A practical example of network no. 3 and the solution to the network design.

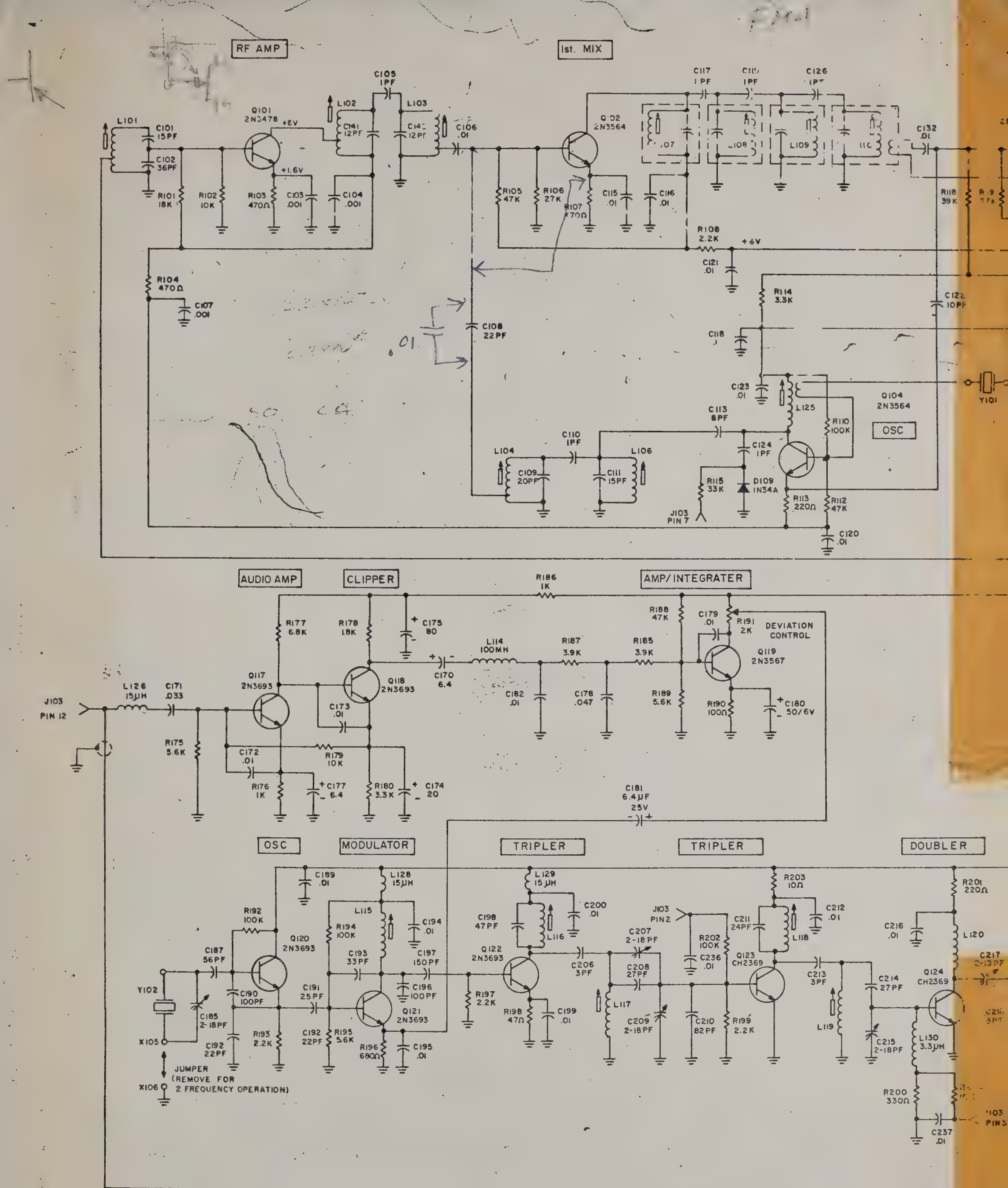
A design example for network 3 is given in Fig 19. The solutions for the other two networks follow the same general trend, so examples for networks 1 and 2 will not be given. In Fig 19 the component "C_{out}" is taken from the manufacturer's data sheet. If it is not available, it can be ignored at the expense of a slight mathematical error in the network determination. By making C1 variable the network can be made to approximate the correct transformation ratio. At the lower frequencies C1 will be fairly large in value. This may require a fixed-value silver-mica capacitor in parallel with a mica compression trimmer to obtain the exact value of capacitance needed. The equations will seldom yield standard values of capacitance.

L1 and L2 of Fig 19 can be wound on powdered-iron toroid cores of suitable cross-sectional area for the power involved. This is explained in an earlier chapter of this book. L1 and L2 should be separated by mounting them apart and at right angles. Alternatively, a shield can be used between the inductors. This will prevent unwanted capacitive and inductive coupling



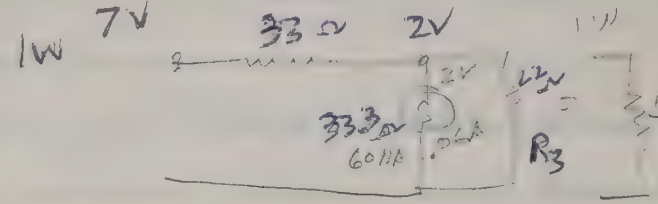
Full Audio
HALF "
1/2 % "

Figure 8-2. Model FM-1 Transceiver Schematic Diagram


RF AMP
1st. MIX
OSC
AUDIO AMP
CLIPPER
AMP/ INTEGRATER
DEVIATION CONTROL
OSC
MODULATOR
TRIPLER
TRIPLER
DOUBLER
Q101 2N3478
Q102 2N3564
Q104 2N3564
Q117 2N3693
Q118 2N3693
Q119 2N3567
Q120 2N3693
Q121 2N3693
Q122 2N3693
Q123 CH2369
Q124 CH2369
L101
C101 15PF
C102 36PF
R101 18K
R102 10K
R103 470Ω
C103 .001
C104 .001
R104 470Ω
C107 .001
L102
C141 12PF
C105 1PF
L103
C142 12PF
C106 .01
R105 47K
R106 27K
R107 470Ω
C115 .01
C116 .01
C117 1PF
C119 1PF
C126 1PF
L107
L108
L109
L110
C132 .01
R118 39K
R108 2.2K
+6V
C121 .01
R114 3.3K
C122 10PF
C118 .1
C108 22PF
C123 .01
L125
Y101
C113 8PF
R110 100K
C110 1PF
L104
C109 20PF
C111 15PF
L106
C124 1PF
R115 33K
D109 1N34A
R113 220Ω
R112 47K
J103 PIN 7
C120 .01
+2V
+1.6V
R186 1K
R177 6.8K
R178 18K
C175 80
L114 100MH
R187 3.9K
R185 3.9K
R188 47K
C179 .01
R191 2K
C170 6.4
C182 .01
C178 .047
R189 5.6K
R190 100Ω
C180 50/6V
J103 PIN 12
L126 15µH
C171 .033
C173 .01
R175 5.6K
C172 .01
R179 10K
R176 1K
C177 6.4
R180 3.3K
C174 20
C181 6.4µF 25V
C189 .01
L128 15µH
L115
C194 .01
R192 100K
R194 100K
C187 56PF
C193 33PF
C197 150PF
C196 100PF
C190 100PF
C191 25PF
Y102
C185 2-18PF
R193 2.2K
C192 22PF
R195 5.6K
R196 680Ω
C195 .01
X105
X106
JUMPER (REMOVE FOR 2 FREQUENCY OPERATION)
L129 15µH
C200 .01
C198 47PF
L116
R197 2.2K
R198 47Ω
C199 .01
C206 3PF
C207 2-18PF
C208 27PF
L117
C209 2-18PF
C210 82PF
J103 PIN2
R202 100K
C236 .01
C211 24PF
R203 10Ω
C212 .01
L118
R199 2.2K
C213 3PF
L119
C214 27PF
C215 2-18PF
R201 220Ω
C216 .01
L120
C217 2-13PF
L130 3.3µH
R200 330Ω
C237 .01
.01
FINAL

for FM-1

Dummy Load .. 1watt ..... 37Ω? 50Ω?



$R_{lamp} = E/I = \frac{2}{.06} = 33.3\,\Omega$

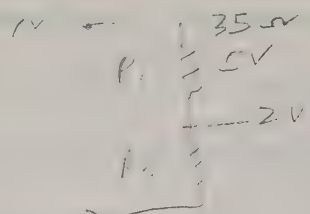
P_{lamp}

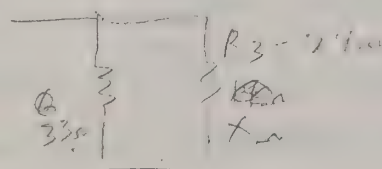
$P = E^2/R \quad E^2 = PR$

$E = \sqrt{PR} = \sqrt{50} = 7.V$

$\frac{250}{7} = 35\,\Omega$

$R_2 = 2/7 \times 50 = \frac{100}{7} = 14\,\Omega$





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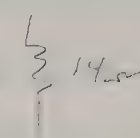
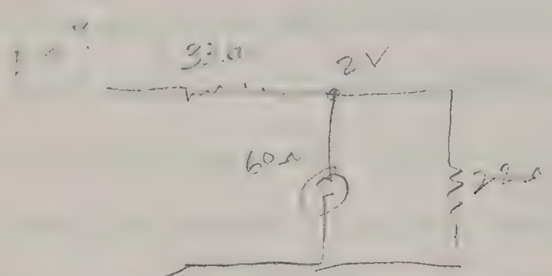


$X = \frac{33 \times 14}{33 - 14} = \frac{462}{19} = 2$

34 33 42 — 33 14 19 — 42 462 19 24Ω



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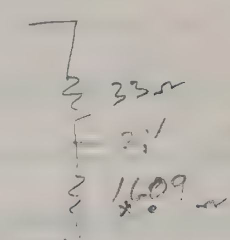

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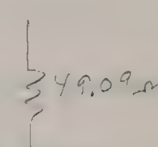


12/27/73

FM1 Frequencies

~~fundamental~~ Test frequency Bob Miller
REC
Signal 153.400 /18 = 8.5222 XMIT
1ST Losc 135.950
IF 17.450
2nd osc 16.993 Mc
IF 0.455

Mt Pisgah Repeater Xmit 146.760
Rec 146.160

FM1:

Receive 146.760 Mc $F_{xTal} = \frac{146.760 - .455\text{Mc}}{9}$ = 16.256111 MC XTAL

1^{ST} IF = 146.760 − 8×16.256111 = 16.71112

2^{nd} IF = 16.71112 − 16.256111 = 0.455 Mc

1^{ST} Local Osc = 8×16.256111 = 130.04888

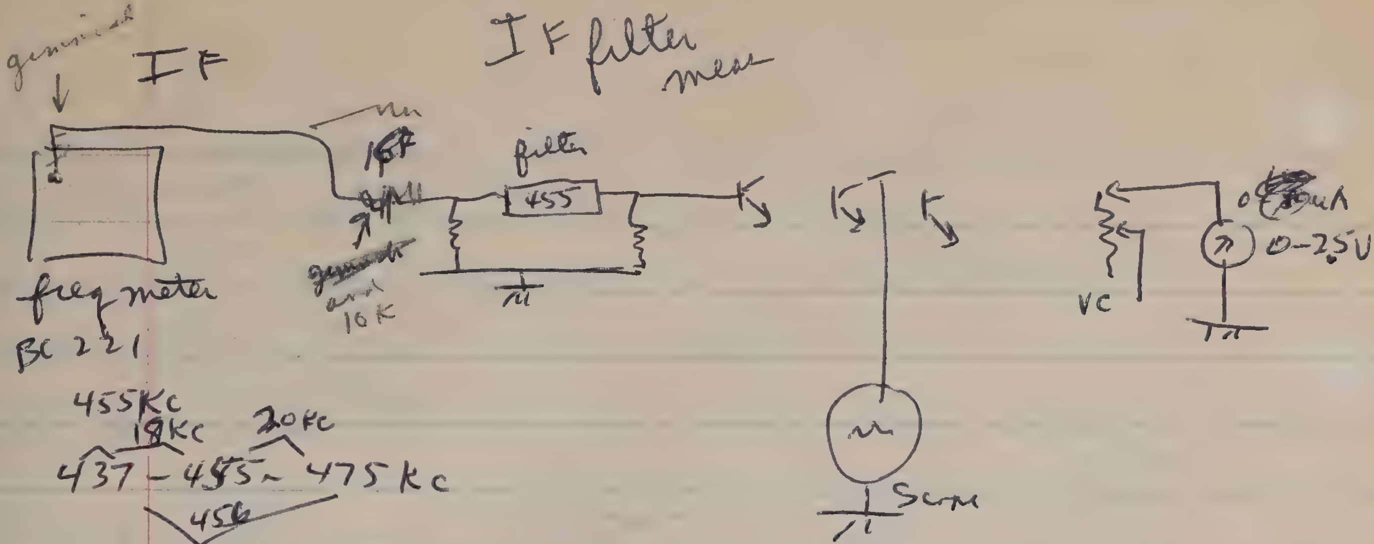
Signal 146.760
~~Im~~ Image (145.85)
osc. 130.04888
Image (113.33776) ~~130.04888~~ IF 16.71112
osc 16.256111
Image (15.80112)
IF 0.455

Diagram showing frequency scheme, RF tuned to 146.760 Mc and rejecting 113.33776 and high IF tuned to 16.71112 Mc and rejecting 15.80112 Mc, and low IF tuned around 455 kc center for a flat bandwidth, and frequency discriminator tuned to 455 kc.

If 455 kc filter center is incorrect by 1 kc, the receive xTal must be shifted 0.111 ~~[illegible]~~ kc. If received signal is incorrect by 1 kc, ~~the~~ Receiver crystal must be shifted 0.111 kc.

Xmit. xtal Freq = 146.160 / 18 = 8.120 Mc

IF filter meas



455KC

$\overbrace{437 - 455}^{18KC} - \overbrace{455 - 475}^{20KC}\ KC$; $\underbrace{437 - 475}_{456}$

Rec "A" → 38KC wide -6dB

"C" $\overbrace{439 - 455}^{16} - \overbrace{455 - 475}^{20}\ KC$; $\underbrace{439 - 475}_{457}$

36KC wide -6dB

Receiver "C"

466 +8	.1V	
460 +2	.05V	
458 0	0V out	
453 -5	.05V	
449 -9	.1V	

0.1Vp-p for 7KC total deviation (460 to 453)

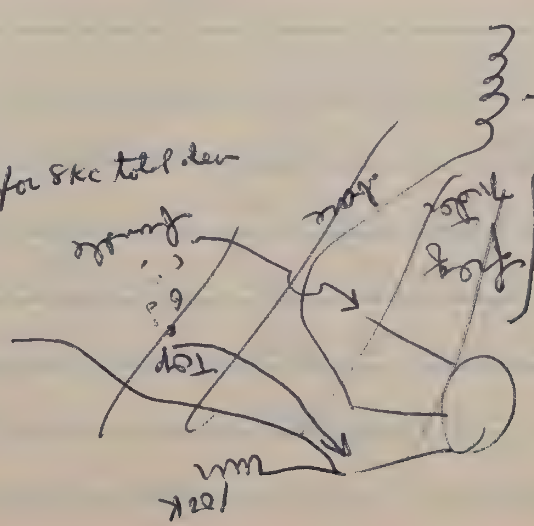
0.2Vpp for 17KC Total dev. (466 to 449)

Rec B

$\overbrace{437 - 455}^{18} - \overbrace{455 - 475}^{20KC}\ KC$; $\underbrace{437 - 475}_{456}$

465	.1V	+9KC
460	+.05V	+4KC
456	0V	0KC
452	.05V	-4KC
448	.1V	-8KC

0.1Vp-p for 8KC total dev (460 to 452)



0.2Vpp for 17KC

FM-1 75

AN-210

Application Note

MV 1876

33 pF at -4V

FM MODULATION CAPABILITIES OF EPICAP VVC'S

Prepared by

Dick Schell

Microwave Devices Group

The author shows by empirical methods that the frequency vs. voltage curve for Epicap voltage variable capacitors is linear for small (sufficient for most FM modulator applications) voltage variations.

A rigorous mathematical explanation of this linear inter-dependence follows the empirical demonstration.

75

MOTOROLA Semiconductor Products Inc.

INTRODUCTION

In most applications FM modulation is accomplished by one of three methods. A mechanical modulator using a capacitor microphone is the simplest system, but is seldom used. The capacitor microphone, being a delicate mechanical device, must be handled carefully. Also, it lacks wide capacity-variation capabilities restricting its application greatly. Finally, it requires a pressure wave input, and, consequently, is not suitable for telemetry applications.

A second system employs a tube whose reactance varies with the modulation signal, and thereby varies the frequency of the oscillator stage used to generate the RF signal. This system has been quite popular, and, in the appropriate environment, functions quite well. As with other electron tube devices it is relatively large; it is easily breakable; and it requires filament power as well as a high-voltage supply.

A third system, usually called the "phase-angle modulation system" employs a combining network to alter the instantaneous frequency of the RF energy already generated by the oscillator stage. Combining networks usually use triodes, although transistors may be used also. Until only recently, transistors have not been used intensively in these applications, due to their power-handling limitations at high frequencies. Naturally, the triodes suffer from the same limitations as does the reactance tube.

Many modern RF systems, particulary those used in the military and aerospace fields, are subjected to environmental stresses which are extremely severe. Solid-state devices with their built-in strength are in general superior to the mechanical and electron tube devices mentioned in the preceding paragraph for these applications. Some of these applications also require high miniaturization can only be achieved with solid-state devices.

Let us consider the desirability of using voltage variable capacitance diodes (VVC) as the variable element for FM modulator applications. Many people mistakenly believe that the nonlinear relationship between the voltage across a VVC and its capacity precludes its use in FM modulation applications. In this paper it will be shown that the Motorola EPICAP™VVC capacity vs. voltage curve varies as (approximately) the inverse 1/2 power and that for most FM modulation applications, this capacity/voltage variation is sufficiently linear for good results.

In order to demonstrate the feasibility of Epicap VVC's for FM modulator applications, the author employs an oscillator circuit, similar to many actual FM modulators, to determine the actual oscillator frequency variation for a given diode voltage variation. From the results of this test it will be shown that over a typical FM bandwidth of 150 kHz Epicap VVCs are suitable for FM modulation applications.

Following the discussion of the bench test, a derivation of the expected theoretical capabilities of the Epicap VVC (for FM modulator applications) is presented. In conclusion it is shown that the theoretical relationship and the experimental data obtained from the test oscillator are in good agreement.

THE BENCH TEST

Before proceeding with a description of the oscillator circuit it should be pointed out that the reader wishing more information on Epicap VVS's should consult appendix A of this paper. If additional applications information on VVC's or complete data sheets are desired they may be obtained by writing to Motorola Semiconductor Products Inc., Technical Information Center, Phoenix, Arizona 85001 (P.O. Box 955).

The oscillator circuit, illustrated in Figure 1, employs a Motorola MPS6511 transistor, designed especially for

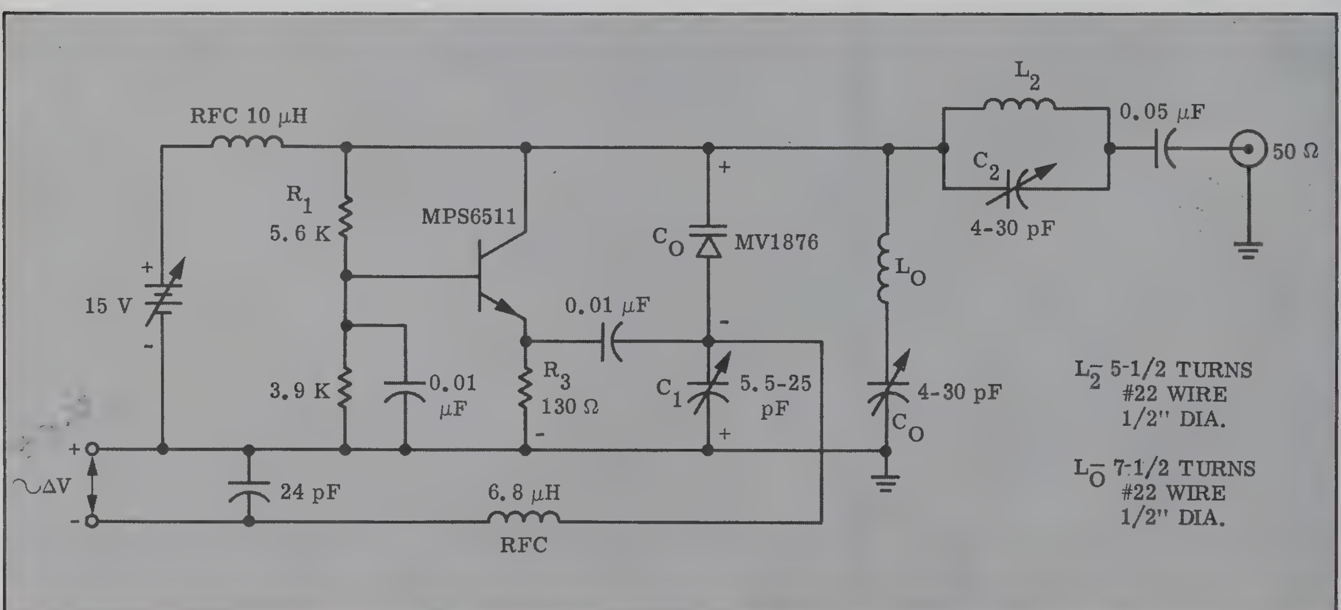


FIGURE 1

---

oscillator applications. The oscillator frequency is 52 MHz. The Epicap VVC chosen for this test circuit is the Motorola MV1876, a silicon epitaxial passivated diode, rated at 33 pF for a reverse bias voltage of -4 volts.

Referring to the schematic, Figure 1, L_2 and C_2 are used to tune out unwanted harmonics; their combined effect approaches a short circuit at the frequency of oscillation. The 6.8 μH RFC and the 24 pF capacitor in the input circuit are used to isolate the external input circuit from the RF circuit of the oscillator. At audio frequencies, however, there is little attenuation from these devices; thus, the input voltage is applied between ground and the positive side of the voltage-variable-capacitor.

Circuit operation was limited to voltage inputs of ±200 mV or less, with the frequency deviations on the order of ±60 kHz or less. Referring to Figure 2, a plot of oscillator frequency vs. input voltage, it can be seen that relatively good linearity can be obtained to at least ±75 kHz making the Epical VVC applicable for commercial FM use (commercial FM is limited to a deviation of ±75 kHz). Using a frequency doubler in conjunction with the FM modulator would give good linearity with an allowable frequency deviation of ±120 kHz, and a center frequency of 104 MHz.

THEORETICAL ANALYSIS OF EPICAP VVC PERFORMANCE IN OSCILLATOR CIRCUIT

In this section we shall analyze the Epicap VVC performance in the test circuit. In order to do this we shall derive $\Delta\omega = f(\Delta V)$, and show that for small ΔV's, V. Many of the equations used in this section are derived in Appendix B; the reader should refer to that Appendix for the details.

Let the value of the input voltage be represented by ΔV. The input voltage is the amount by which the reverse bias voltage under audio frequency modulation deviates from its quiescent value under no signal conditions.

The polarity of ΔV is chosen such that a positive ΔV corresponds to an increase in the VVC reverse bias voltage. With reference to Figure 1, it can be seen that the quiescent value of V, that is, when $\Delta V = 0$, is 15 volts. Consequently, the reverse bias voltage across the VVC at any given time may be given by $15 + \Delta V$, where ΔV can be either positive, negative, or zero.

The diode capacitance C_D is given by the equation*

$$C_D = \frac{V_1^{\alpha}\ C_{D1}}{V^{\alpha}} = \frac{V_2^{\alpha}\ C_{D2}}{V^{\alpha}}$$

where C_D = total diode capacitance
V = reverse bias voltage across the diode
V_1 and V_2 are two values of the voltage about the quiescent value, and C_{D1} and C_{D2} are their corresponding diode capacitances.

$$\alpha = \frac{\ln C_{D2} / \ln C_{D1}}{\ln (V_1/V_2)} \doteq \frac{\log C_{V1} - \log C_{V2}}{\log \ldots} \tag{1}$$

Clearly, a variation in C_D results in a change in the frequency of oscillation. In order to derive $\Delta\omega = f(\Delta V)$, we first derive $\Delta\omega = f(\Delta C_D)$, then $\Delta C_D = f(\Delta V)$. By combining the latter two results we naturally arrive at the first result. The derivation of $\Delta\omega = f(\Delta C_D)$, given in Appendix B, results in the expression:

$$\Delta\omega = \frac{\omega_o^2}{2\omega} \frac{(K_6 - K_7)}{(K_7 + C_D)} \Delta C_D$$

where ω_o^2, K_6 and K_7 are constants determined by the circuit parameters defined in Appendix B.

Since these derivations are carried out in detail in the Appendix B they need not be repeated here, however, it is instructive to examine which approximations have been made in the derivation, and, consequently, limit the accuracy of the result. In the Appendix we start with the relation:

$$\omega^2 = \omega_o^2 \left(\frac{C_D + K_6}{C_D + K_7} \right)$$

*Refer to Appendix A

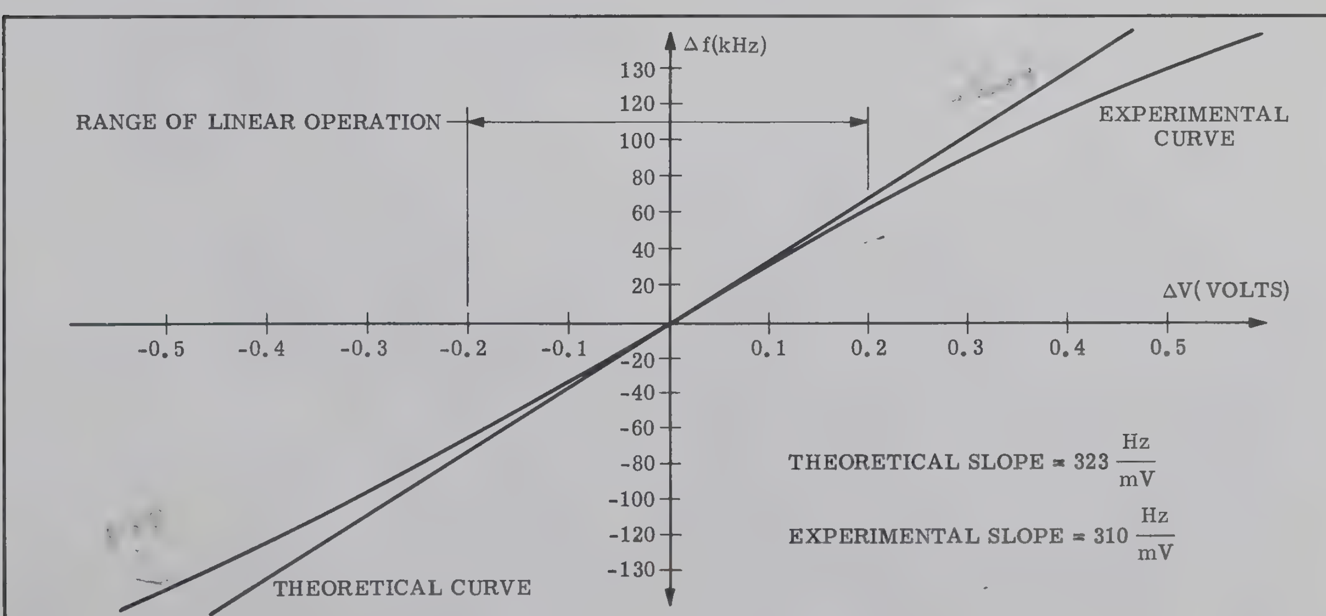


FIGURE 2 — COMPARISON OF THEORETICAL AND EXPERIMENTAL RESULTS

In order to obtain $\Delta\omega = f(\Delta C_D)$ from the above result several assumptions are necessary. Let ω be the frequency of oscillation corresponding to a voltage-variable capacitor capacitance C_D, and $\omega + \Delta\omega$ correspond to the VVC capacitance $C_D - \Delta C_D$. In the derivation it is necessary that $(\Delta\omega)^2$ be small compared to $(2\,\Delta\omega)\omega$. Since ω is 52.0 MHz, and for linear operation the maximum $\Delta\omega$ is only about 60 kHz, it can be seen that this is a good assumption. Also, it is assumed that the denominator $C_D - \Delta C_D \approx C_D$ this is a good assumption provided the quiescent value of V and the small input voltages lead to small variations in capacitance.

The expression giving $\Delta C_D = f(\Delta V)$, equation 9 in Appendix B is:

$$\Delta C_D = \frac{C_{DO}\left[\alpha\Delta V\right]}{V^{1+\alpha}} \qquad (2)$$

Again, it is desirable to examine the assumptions inherent in deriving the above expression. Referring to Appendix B for details, one can see that $V^{2\alpha}$ has been substituted for the quantity $(V + \Delta V)^{\alpha}\,(V)^{\alpha}$. Also, all but the first two terms of the binomial expansion of $(V + \Delta V)^{\alpha}$ have been neglected.

Combining equations (1) and (2) we obtain the following equation:

$$\Delta\omega = \frac{\omega}{2}\;\frac{K_6 - K_7}{(K_6 + C_D)(K_7 + C_C)}\left(\frac{\alpha C_{DO}}{V^{1+\alpha}}\right)\Delta V$$

It can be seen from the above equation that the frequency deviation $\Delta\omega$ is proportional to the change of input voltage ΔV no matter what the value of α is.

The above equation has been evaluated for the circuit shown in Figure 1. The result of this evaluation is a frequency deviation vs. voltage slope of 323 Hz/mV.

Referring to Figure 2, it can be seen that this slope (323 Hz/mV) is in good agreement with the emperically derived slope of 310 Hz/mV. The assumptions imposed upon the circuit analysis limited the accuracy of the derivation, otherwise even better agreement would have been obtained. In particular, the main reason for the difference between the two results probably results for the neglection of the higher terms of the binomial expansion of $V^{2\alpha}$.

APPENDIX A — HOW EPICAPS WORK

Epicaps are voltage-variable capacitors based on PN junction theory. Conventionally speaking, when we refer to a semiconductor diode we normally visualize a 2-terminal p-n junction operated in the forward conduction region (as a rectifier) or in the reverse avalanche region (as a zener diode). From this standpoint, the word diode applied to a Epicap is actually a misnomer — for while the Epicap is indeed a 2-terminal PN junction, it operates neither as a rectifier, nor as an avalanche device. Rather, it operates principally in the region between forward conduction and reverse breakdown — the very region in which a conventional diode is considered to be cut off.

In this operating region the PN junction can be represented by a capacitor in series with a resistor,

FIGURE 1

The capacitance, known as junction capacitance, is inherently associated with all PN junctions and, while it represents an undesirable parasitic in conventional diode operation, it is the specific mechanism that permits the device to function as an Epicap, or voltage-variable capacitor. This is true because the capacitance value, as will be seen later, actually varies as a function of applied voltage. This factor cannot only be used for electric tuning but also for harmonic generation and parametric amplification.

The resistor is the result of bulk and contact resistance of the semiconductor material. In Epicap operation this resistance is the primary parasitic affecting Epicap quality. Great pains are taken in Epicap design, therefore, to hold this resistance value to an absolute minimum.

The cause and behavior of the junction capacitance can be determined from basic semiconductor theory, as follows:

When a junction is formed between n-type and p-type material, there is a cross-migration of charges across the junction. Electrons from the n-region cross the junction to neutralize positive carriers near the junction in the p-region, and "holes" from the p-region cross the junction to neutralize the "excess" electrons near the junction in the n-region. As a result of this migration, all free charged particles are swept out of the immediate vicinity of the junction area. And, in the process, a contact potential or space charge (about 0.5 V for silicon) appears across the junction, Fig. 2a.

This structure acts very much like a slightly charged capacitor, with the depletion layer representing the dielectric and the semiconductor material adjacent to the depletion layer representing the two conductive plates.

If an external voltage is connected across the p-n junction so as to reinforce the contact potential (reverse bias), the depletion layer increases, resulting in a capacitance decrease, Fig. 2b. If a forward voltage is applied, the depletion layer decreases, Fig. 2c. However, if the external forward voltage is made large enough to overcome the contact potential, forward conduction occurs and the capacitance effect is destroyed.

It is obvious, therefore, that the value of the junction capacitance is a function of the externally applied voltage, so long as the junction itself remains reverse biased. This relationship is:

$$C = \frac{C_o}{(1 + V/\phi)^{\gamma}} = \frac{\phi^{\gamma} C_o}{(\phi + V)^{\gamma}} \qquad (4)$$

where:

C = capacitance at voltage V

C_o = capacitance at zero bias

V = voltage across the diode (reverse bias)

ϕ = contact potential

γ = power law of the junction, determined by impurity gradient.

The exponent is a function of the impurity gradient of the PN junction. It may vary from approximately 1/2, for step junctions, to about 1/6 for specially graded junctions. For electric tuning the greatest capacity-voltage variation is desired so the step junction is generally used.

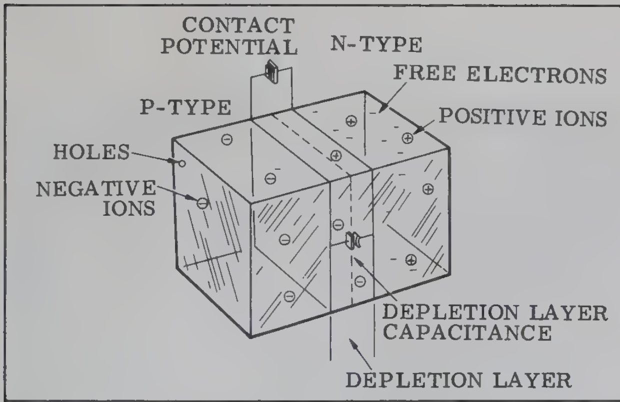


FIGURE 2 (A) — A REPRESENTATIVE P-N JUNCTION
The battery represents the contact potential which must be overcome before current can flow. Current carriers act as a capacitor plates and the depletion layer is the dielectric.

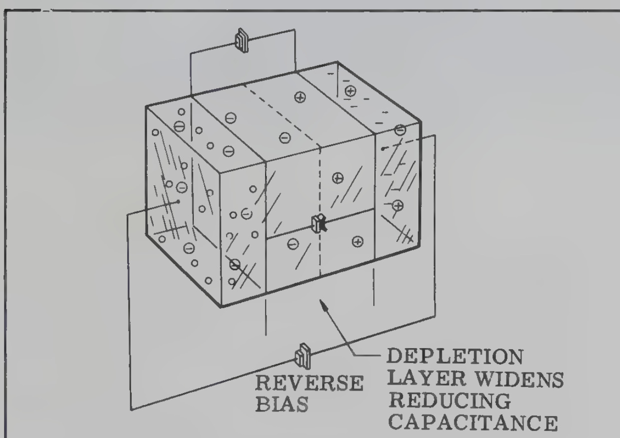


FIGURE 2 (B) — REVERSE VOLTAGE FORCES
carriers away from junction. This widens the depletion layer and reduces capacitance.

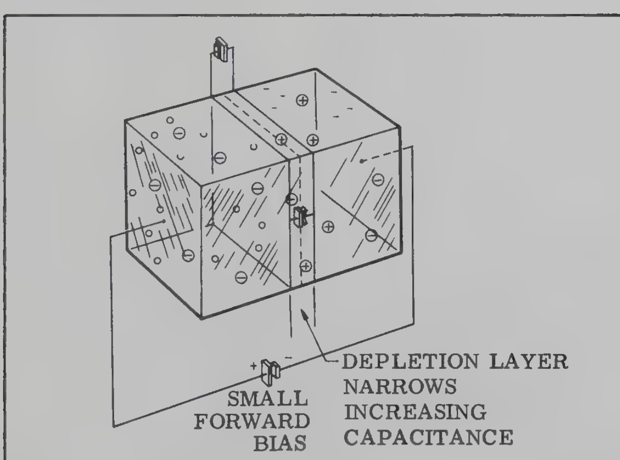


FIGURE 2 (C) — FORWARD VOLTAGE FORCES
carriers closer to junction or across junction again changing capacitance.

All PN junctions have to be protected from the corrosive effects of the atmosphere; therefore, packages or housings are used. Associated with the package and the internal connections to the junctions are parasitic reactances. The complete equivalent circuit of a packaged PN junction operated in the reverse voltage region for electric tuning, is shown in Fig. 3. The voltage-variable capacitance is C_j; R_S is the series resistance; R_p is the junction shunt resistance which generally can be neglected; L_S is the lead inductance and C_C is the case capacitance.

The admittance of an Epicap including all parameters of Fig. 3 is:

$$y = j\omega C_c + \cfrac{1}{R_s + j\omega L_s + \cfrac{1}{\cfrac{1}{R_p} + j\omega C_j}} \qquad (5)$$

where

R_p is high enough to be neglected

$$y = j\omega C_c + \frac{j\omega C_j}{1-\omega^2 L_s C_j + j\omega C_j R_s} \qquad (6)$$

Inherent junction Q is defined as:

$$Q = \frac{1}{\omega C_j R_s} \qquad (7)$$

If Q is high compared to $1-\omega^2 L_S C_j$ the Epicap has a capacitance given by

$$Ceq = C_c + \frac{C_j}{1-\omega^2 L_s C_j} \qquad (8)$$

Equation 8 shows how equivalent capacity can be modified by L_S and C_C.

Usually operation is well below the self-resonant frequency $\omega_o = 1/L_S C_j$ so that the total capacity is given by

$$C_T = C_c + C_j \qquad (9)$$

and in terms of voltage

$$C_T = C_c + \frac{C_o}{\left(1 + \frac{V_R}{\phi}\right)^{\gamma}} \qquad (10)$$

where:

γ = 0.5 for step junction

ϕ = 0.5 volts

The total Q is then

$$Q = \frac{1}{\omega C_t R_s} \qquad (11)$$

The important device information is given by eqs. (10) and (11) with eq. (8) being significant at frequencies approaching self-resonance.

In the next section the parameters of specific Motorola Epicaps will be given and comparisons made to previously available voltage tunable capacitors.

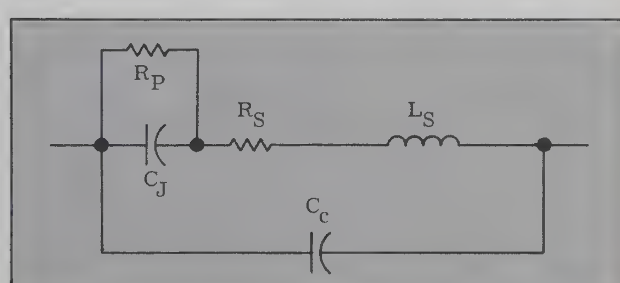
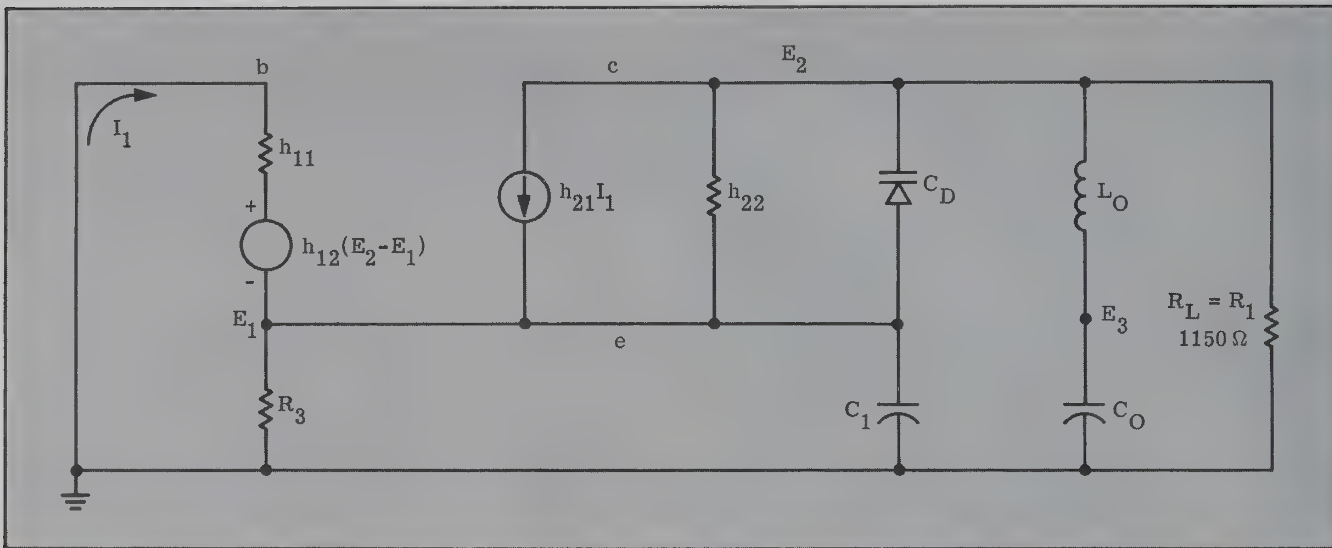


FIGURE 3 — EQUIVALENT CIRCUIT EPICAP

APPENDIX B

Replacing transistor by h-parameter representation and drawing only RF circuit of Figure 1 we have



Writing node equations for the above circuit we obtain

(1) $$E_1 \left(\frac{1}{R_3} + C_1 S\right) + (E_1 - E_2)(h_{22} + C_D S) + \left[E_1 + h_{12}(E_2 - E_1)\right]\left(\frac{1}{h_{11}}\right)$$

$$- h_{21} I_1 = 0$$

(2) $$(E_2 - E_1)(h_{22} + C_D S) + h_{21} I_1 + (E_2 - E_3)\left(\frac{1}{L_o S}\right) + \frac{E_2}{R_L} = 0$$

(3) $$E_3 (C_o S) + (E_3 - E_2)\left(\frac{1}{L_o S}\right) = 0$$

from Eq 3 $E_3 = \dfrac{E_2}{1 + L_o C_o S^2}$ $\qquad (E_2 - E_3) = \dfrac{E_2 L_o C_o S^2}{1 + L_o C_o S^2}$

plugging this in equation 2

$$(E_2 - E_1)(h_{22} + C_D S) + h_{21} I_1 + \frac{E_2 C_o S}{1 + L_o C_o S^2} + \frac{E_2}{R_L} = 0$$

$$I_1 = -\frac{E_1 + h_{12}(E_2 - E_1)}{h_{11}}$$

$$(E_2 - E_1)(h_{22} + C_D S) - h_{21}\frac{E_1 + h_{12}(E_2 - E_1)}{h_{11}} + E_2\left(\frac{C_o S}{1 + L_o C_o S^2} + \frac{1}{R_L}\right) = 0$$

$$E_2\left(h_{22} + C_D S - \frac{h_{21} h_{12}}{h_{11}} + \frac{C_o S}{1 + L_o C_o S^2} + \frac{1}{R_L}\right)$$

$$- E_1\left(h_{22} + C_D S + \frac{h_{21}}{h_{11}} - \frac{h_{21} h_{12}}{h_{11}}\right) = 0$$

Assume h-parameters are constant under operating conditions and define

$$K_1 = h_{22} - \frac{h_{21} h_{12}}{h_{11}} + \frac{1}{R_L}, \quad K_2 = h_{22} + \frac{h_{21}}{h_{11}} - \frac{h_{21} h_{12}}{h_{11}}$$

$$\therefore \; E_2\left(K_1 + C_D S + \frac{C_o S}{1 + L_o C_o S^2}\right) - E_1 (C_D S + K_2) = 0$$

$$E_1 = E_2\left(K_1 + C_D S + \frac{C_o S}{1 + L_o C_o S^2}\right) \Big/ C_D S + K_2 \qquad (4)$$

going now to equation 1

$$E_1\left(\frac{1}{R_3} + C_1 S + h_{22} + C_D S + \frac{1 - h_{12}}{h_{11}}\left[1 + h_{21}\right]\right)$$

$$- E_2\left[h_{22} + C_D S - \frac{h_{12}}{h_{11}}(1 + h_{21})\right] = 0$$

let $K_3 = \dfrac{1}{R_3} + h_{22} + \dfrac{1 - h_{12}}{h_{11}}\left[1 + h_{21}\right]$

& $K_4 = h_{22} - \dfrac{h_{12}}{h_{11}}(1 + h_{21})$

$$E_1 (K_3 + C_1 S + C_D S) - E_2 (C_D S + K_4) = 0 \qquad (5)$$

combining equations 4 & 5

$$E_2\left[\frac{\left(K_1 + C_D S + \frac{C_o S}{1 + L_o C_o S^2}\right)(K_3 + C_1 S + C_D S)}{C_D S + K_2} - C_D S - K_4\right] = 0$$

thus

$$\frac{\left(K_1 + C_D S + \frac{C_o S}{1 + L_o C_o S^2}\right)(K_3 + C_1 S + C_o S)}{C_D S + K_2} - C_D S - K_4 = 0$$

$$K_1 K_3 + C_D S K_3 + \frac{C_o S K_3}{1 + L_o C_o S^2} = K_1 C_1 S + C_D C_1 S^2$$

$$+ \frac{C_1 C_o S^2}{1 + L_o C_o S^2} + K_1 C_D S + C_D{}^2 S^2 + \frac{C_o C_D S^2}{1 + L_o C_o S^2} - C_D{}^2 S^2$$

$$- K_4 C_D S - K_2 C_D S - K_2 K_4 = 0$$

Separating out the odd powers of s we get

$$K_3 C_D S\left[1 + L_o C_o S^2\right] + C_o S K_3 + K_1 C_1 S\left[1 + L_o C_o S^2\right]$$

$$+ K_1 C_D S\left[1 + L_o C_o S^2\right] - K_4 C_D S\left[1 + L_o C_o S^2\right] - K_2 C_D S\left[1 + L_o C_o S^2\right] = 0$$

or

$$C_DK_3 + C_DK_3L_oC_oS^2 + C_oK_3 + C_1K_1 + C_1K_1L_oC_oS^2$$

$$- C_oK_4 - C_DK_4L_oC_oS^2 - C_DK_2 - C_DK_2L_oC_oS^2 = O$$

Solving for S^2 we obtain

$$S^2 = \frac{\omega_o^2 \left[C_D(K_2 + K_4 - K_3) - C_oK_3 - C_1K_1\right]}{C_D(K_3 - K_4 - K_2) + C_1K_1}$$

where $\omega_o^2 = \frac{1}{L_oC_o}$

$$S^2 = \frac{- \omega_o^2 \left[C_D + \frac{C_oK_3 + C_1K_1}{K_3 - K_4 - K_2}\right]}{C_D + \frac{C_1K_1}{K_3 - K_4 - K_2}}$$

Defining K_6 & K_7 as $K_6 = \frac{C_oK_3 \,\&\, C_1K_1}{K_3 - K_4 - K_2}$

and $K_7 = \frac{C_1K_1}{K_3 - K_4 - K_2}$

we have $$S^2 = \frac{-\omega_o^2 \left[C_D + K_6\right]}{\left[C_D + K_7\right]}$$

$$S^2 = -\omega^2$$

$$\omega^2 = \omega_o^2 \left[\frac{C_D + K_6}{C_D + K_7}\right] \qquad (6)$$

To determine $\Delta\omega$ in terms of ΔC_D let

$$C_D = C_D - \Delta C_D$$

$$\omega = \omega + \Delta\omega$$

$$\omega^2 + (2\Delta\omega)(\omega) + (\Delta\omega)^2 = \omega_o^2 \left[\frac{K_6 + C_D - \Delta C_D}{K_7 + C_D - \Delta C_D}\right] \qquad (7)$$

Subtracting equation 6 from equation 7 and neglecting the $(\Delta\omega)^2$ term

$$\frac{2(\Delta\omega)(\omega)}{\omega_o^2} = \frac{K_6 + C_D - \Delta C_D}{K_7 + C_D - \Delta C_D} - \frac{K_6 + C_D}{(K_7 + C_D)}$$

$$= \frac{C_D(K_6 - K_7)}{(K_7 + C_D - \Delta C)(K_7 + C_D)} \doteq \frac{\Delta C\,(K_6 - K_7)}{(K_7 + C_D)^2}$$

$$\therefore \quad \Delta\omega = \frac{\omega_o^2 (K_6 - K_7)}{2\omega\,(K_7 + C_D)^2}\,\Delta C_D \qquad (8)$$

Now we must determine ΔC_D in terms of ΔV so let

$$C_D = \frac{C_{DO}}{V^\alpha} \quad \text{and} \quad C_D - \Delta C_D = \frac{C_{DO}}{(V + \Delta V)^\alpha}$$

$$\Delta C_D = \left[\frac{C_{DO}}{V^\alpha} - \frac{C_{DO}}{(V + \Delta V)^\alpha}\right] = \frac{C_{DO}\left[(V + \Delta V)^\alpha - V^\alpha\right]}{(V^\alpha)(V + \Delta V)^\alpha}$$

$$\Delta C_D \doteq \frac{C_{DO}\left[(V + \Delta V)^\alpha - V^\alpha\right]}{V^{2\alpha}}$$

Applying the binomial expansion to $(V + \Delta V)^\alpha$ we get

$$V^\alpha + \alpha V^{\alpha - 1}\Delta V + \frac{\alpha(\alpha - 1)}{2!}V^{\alpha - 2}(\Delta V)^2 + \text{---}$$

For small ΔV we can neglect all but the first two terms. For ΔC we now have,

$$\Delta C_D = \frac{C_{DO}\left[\alpha\Delta V\right]}{V^{1 + \alpha}} \qquad (9)$$

Plugging this expression for ΔC into the equation for $\Delta\omega$, we obtain a linear relation between $\Delta\omega$ and ΔV

$$\Delta\omega = \frac{\omega_o^2}{2\omega}\,\frac{(K_6 - K_7)}{(K_7 + C)^2}\,\frac{C_{DO}\left[\alpha\Delta V\right]}{V^{1 + \alpha}}$$

Since $\omega^2 = \omega_o^2\left[\frac{K_6 + C_D}{K_7 + C_D}\right]$ or $\frac{\omega_o^2}{2\omega} = \frac{\omega}{2}\left[\frac{K_7 + C_D}{K_6 + C_D}\right]$

$$\Delta\omega = \frac{\omega}{2}\left[\frac{(K_6 - K_7)}{(K_6 + C_D)(K_7 + C_D)}\right]\frac{C_{DO}\alpha}{V^{1 + \alpha}}\,\Delta V \qquad (11)$$

The circuit parameters under the conditions of operation are

ω = 52 MHz C_O = 26 pF and C_1 = 21 pF

For the diode

C_D = Capacitance for a 15 V reverse bias

C_D = 19.4 pF V = 15 volts

α = 0.465 $+\Delta V \Rightarrow$ increase reverse bias

C_{DO} = 68.3 pF/

For the transistor

h_{11} = 128 ohms h_{12} = 0.0322

h_{21} = 18.0 h_{22} = 5.44 mmhos

$$K_1 = h_{22} - \frac{h_{21}h_{12}}{h_{11}} + \frac{1}{R_L}, \quad R_L = 49.5\,\Omega$$

$$K_1 = 5.44 \times 10^{-3} - \frac{0.580}{128} + \frac{1}{49.5}$$

$$\underline{K_1 = 21.1 \times 10^{-3}\ \mho}$$

$$K_2 = h_{22} + \frac{h_{21}}{h_{11}} - \frac{h_{21}h_{12}}{h_{11}}$$

$$K_2 = 5.44 \times 10^{-3} + \frac{18.0}{128} - 4.53 \times 10^{-3} \qquad \underline{K_2 = 142 \times 10^{-3}\ \mho}$$

$$K_3 = \frac{1}{R_3} + h_{22} + \frac{1 - h_{12}}{h_{11}}\left[1 + h_{21}\right] \qquad R_3 = 130\,\Omega$$

$$K_3 = 7.70 \times 10^{-3} + 5.44 \times 10^{3} + \frac{1 - 0.032}{128}\left[19\right]$$

$$\underline{K_3 = 157 \times 10^{-3}\ \mho}$$

$$K_4 = h_{22} - \frac{h_{12}}{h_{11}}(1 + h_{21})$$

$$K_4 = 5.44 \times 10^{-3} - \frac{0.0322}{128} \quad (19)$$

$$\underline{K_4 = 0.96 \times 10^{-3}\ \mho}$$

$$K_6 = C_O K_3$$

$$K_6 = \frac{C_O K_3 + C_1 K_1}{K_3 - K_4 - K_2}$$

$$\& \ K_7 = \frac{C_1 K_1}{K_3 - K_4 - K_2}$$

$$K_3 - K_4 - K_2 = 14 \times 10^{-3}\ \mho$$

$$C_1 K_1 = 0.443 \text{ pF} - \mho$$

$$C_O K_3 = 4.08 \text{ pF} - \mho$$

$$\therefore \quad K_6 = 323 \text{ pF}$$

$$K_7 = 31.4 \text{ pF}$$

$$\Delta W = \frac{W}{2} \alpha \frac{K_6 + K_7}{(K_6 + C_D)(K_7 + C_D)} \frac{C_{DO}}{V^{1.465}}$$

Therefore

$$\Delta W = \frac{52}{2}(0.465)\frac{354}{(50.8)(342)}\frac{68.3}{52} \quad \Delta V$$

$$\Delta W = \left(0.323 \frac{\text{MHz}}{\text{V}}\right)\Delta V, \text{ or, } \Delta W = \left(323 \frac{\text{Hz}}{\text{MV}}\right) \Delta V$$

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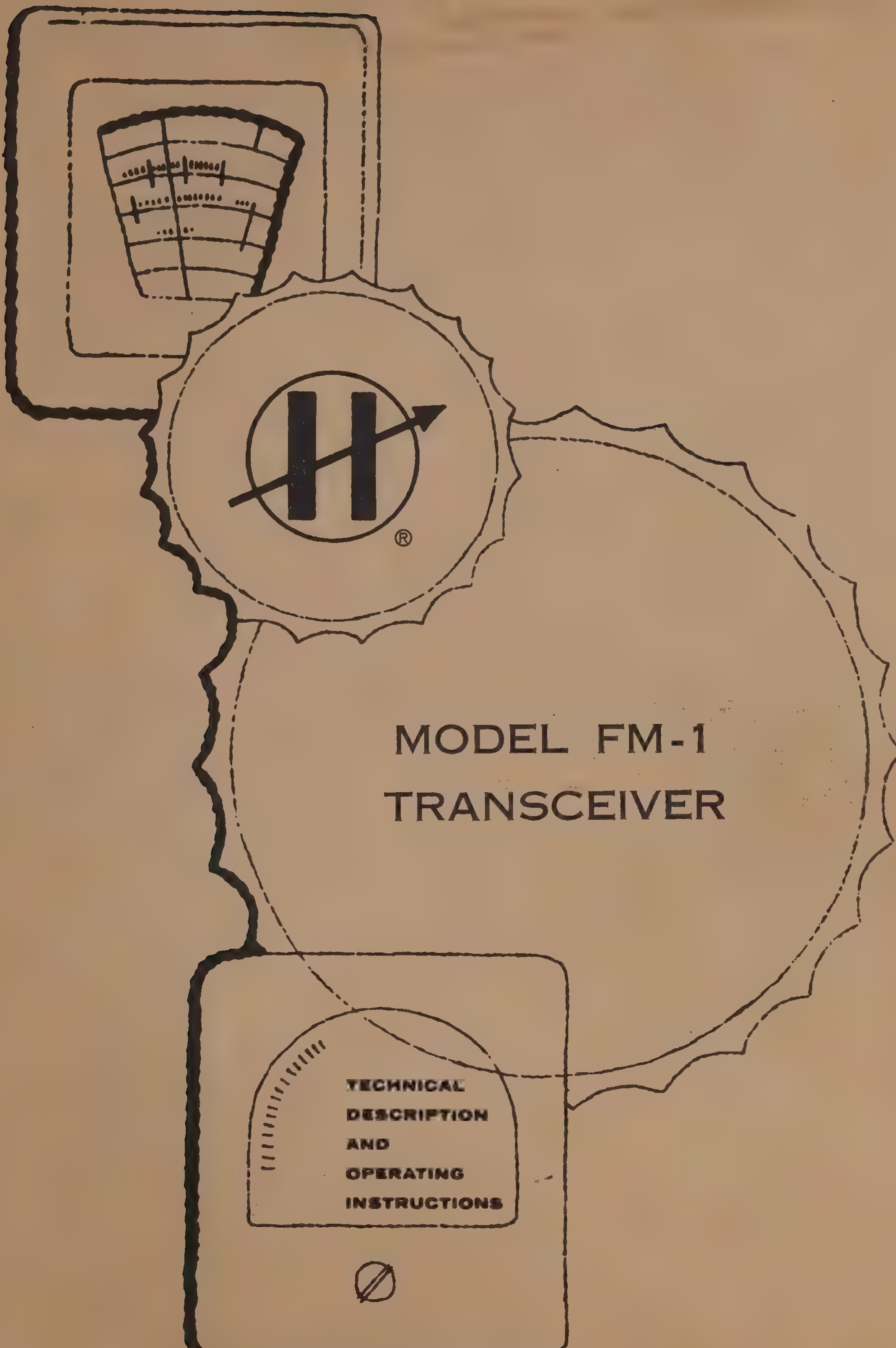

HAMMARLUND

Hammarlund Manufacturing Company, Inc.
A Giannini Scientific Co.
73-88 Hammarlund Dr., Mars Hill, N. C.
Export Department: 13 East 40th Street, New York 16, N. Y.

75

11/-/73 [illegible] 1 board lacks Transistor, test socket, potentiometer, F101, [illegible]

253-0929

11/2-/73 [illegible] 2 boards; one [illegible] chassis No 4051, one [illegible] with [illegible]

3 loudspeakers, 1 damaged

Pair xtals: T 153.400, R 153.400

[illegible] ordered [illegible] xtals from [illegible] 0.0025% [illegible]

OPERATION AND MAINTENANCE MANUAL

Model FM-1 Transceiver

Manufactured By
Hammarlund Manufacturing Co.
Mars Hill, North Carolina

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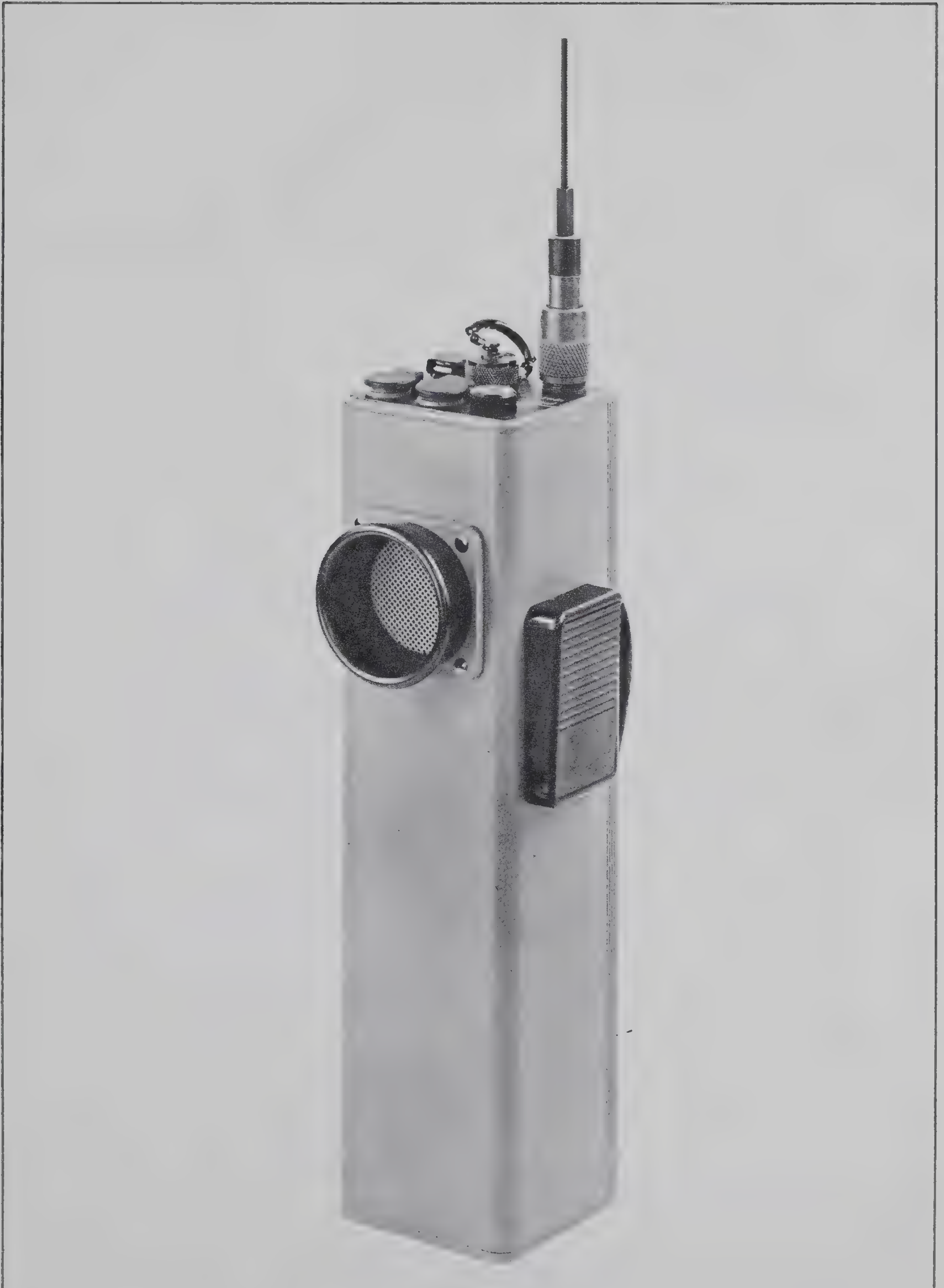


Figure 1-1. Model FM-1 Handheld Transceiver.

SECTION I

INTRODUCTION

1-1 PURPOSE OF EQUIPMENT

1-2 The Hammarlund Model FM-1 handheld transceiver (figure 1-1) is designed to provide reliable communication from a portable position to a portable or a fixed site. The FM-1 has been designed to be readily carried in the left hand. The basic equipment provides voice communication by using FM modulation. Accessory kits allow the equipment to be converted to two-channel operation and/or MCW (modulated continuous wave) operation. The equipment has been designed to work with other FM-1 or FM-5 equipment. However, the equipment is also capable of working with other FM equipment provided that (1) both equipments are on the same frequency, and (2) both equipments use the same deviation in both the receive and transmit conditions. Frequency of operation is 150 - 172 mc.

1-3 FUNCTIONAL DESCRIPTION

1-4 The Model FM-1 equipment operates from eight 1.5 volt D cells which are carried inside the unit, or from an external supply of 12 volts. All equipments are transistorized for minimum battery drain and maximum efficiency.

1-5 BATTERY INSTALLATION

1-6 The transceiver is loaded with eight 1.5 volt D cells. The bottom plate is removed by undoing the large head bolt with a coin or screwdriver. The batteries are inserted as shown on the transceiver labelling. Care must be used to insert the cells in the proper direction, making certain that no one cell is turned around.

1-7 PHYSICAL DESCRIPTION

1-8 OPERATIONAL CHARACTERISTICS AND EFFECTIVE RANGE

1-9 Normal handheld operation requires the use of the standard whip antenna. Other antennas may also be operated with the FM-1 as described in Section III, paragraph 3-6 through 3-12.

1-10 The FM-1 is designed especially for city operation among high levels of impulse interference. The noise immune squelch will not normally break on ignition and other forms of electrical interference. The FM-1, when working into a base station FM-5, may be expected to operate effectively across cities up to distances of 5 kilometers or more provided the FM-5 antenna is above surrounding buildings. In weak signal areas it is important that the FM-1 be held vertical, and not slanted at 45° angles.

1-11 When the FM-1 is connected to the ground plane antenna, normal communication may be expected to slightly exceed line-of-sight distance antenna to antenna.

1-12 Increased operating distance over the standard whip antenna may be obtained by use of the high gain tactical antenna.

SECTION II

SPECIFICATIONS

2-1 GENERAL

2-2 Specifications for the Model FM-1 are provided in Table 2-1.

2-3 TRANSISTOR COMPLEMENT

2-4 The transistor complement for the equipment is provided in Table 2-2.

2-5 DIODE COMPLEMENT

2-6 The diode complement for the equipment is provided in Table 2-3.

2-7 FUSE COMPLEMENT

2-8 The fuse complement for the equipment is provided in Table 2-4.

2-9 CRYSTAL SPECIFICATIONS

2-10 The crystal specifications for the equipment are provided in Table 2-5.

Table 2-1. Model FM-1 Transceiver Specifications.

TRANSMITTER

Minimum Carrier Power Output 161

Minimum RF power output over the full frequency range (150 – 172 mc): 1 watt at 12 volts.

Carrier Frequency Stability ±4.025KC

Total frequency drift for any cause does not exceed ±0.0025% of the assigned center frequency from -30° to +50°C ambient.

Modulation

? ±5 KC Narrow Band, amateur 2M

±15 kc modulation deviation – wide band.

40 F3 modulation pre-emphasized in accordance with EIA standards.

? 16? F3

Spurious and Harmonic Radiation

All spurious radiation is at least 40 db below level of carrier.

FM Hum and Noise Level

At least 40 db below standard test modulation where full-rated-system deviation is ±15 kc ("D" cell supply or external 12-volt battery not charging).

AM Hum and Noise Level

The ratio of the peak ac voltage to the dc voltage detected from the carrier does not exceed -35 db.

256 – 800 – 2500 BW = 2,244 c/s

Modulation Limiting 1000 c/s geometric mean

Full system deviation is not exceeded for any frequency from 400 – 2500 cps

BW = 2100 cps

Modulation Limiting (cont'd)

for an input level 20 db above the level producing 2/3 rated system deviation at 1000 cps.

Audio Frequency Harmonic Distortion

10% maximum, with standard test modulation (EIA).

Audio Frequency Response

The audio response does not vary more than +2 or -8 db from a true 6 db per octave pre-emphasis characteristic from 400 to 2500 cps as referred to the 1000 cps level.

Output Impedance

Suitable for whip antenna, or to match an external 50-ohm ground plane type antenna.

Duty Cycle NOT DESIGNED FOR 1 WATT OUTPUT CONTINUOUS OR AMATEUR SERVICE.

6 seconds receive at rated audio power output, 6 seconds transmit at rated RF power output, and 48 seconds in the standby condition.

Current Drain

Maximum current drain with 12 volts dc at full rated RF power output is 350 milliamperes. $P = EI = 4.2W \times \frac{6\,sec}{60\,sec}$ duty cycle xmit $= 0.420W$ xmit

$0.48W \times \frac{6}{60}$ duty cycle Rec $= .048$

$0.096W \times \frac{48}{60}$ $= .076$

0.544 watts average

RECEIVER

Sensitivity

Better than 0.7 μv for 20 db quieting.

0.7 microvolts is the maximum amount of signal from an unmodulated standard input signal source that is required to produce 20 decibels of noise quieting measured at the receiver audio output.

Squelch Sensitivity

0.35 microvolts is the maximum value of the standard test input signal source which will open the receiver squelch. The squelch control is adjustable with screwdriver, and is accessible from the top panel behind a snap-type waterproof cover.

Modulation Acceptance Bandwidth ? ±5 KC narrowband

Minimum modulation acceptance bandwidth is ±15 KC (wideband).

Adjacent Channel Selectivity

Adjacent channel selectivity is a minimum of 50 db at ±60 KC.

Spurious and Image Response Attenuation

At least 40 db down at all frequencies.

Oscillator Stability ±4.025 KC

Total frequency drift for any cause does not exceed ±0.0025% of the assigned

Table 2-1. Model FM-1 Transceiver Specifications. (cont'd)

Oscillator Stability (cont'd)

center frequency from -30° to +50°C ambient. Oscillator crystals are hermetically sealed in HC-25/U holders. The local oscillator is adjustable electrically so that the receiver may be tuned to the exact operating frequency.

Residual Hum and Noise Level

At least 40 db down from rated output with standard test modulation ("D" cell supply or external 12-volt battery not charging).

Audio Frequency Response

Within +2 and -8 db of a standard 6 db per octave de-emphasis curve over the range of 400 - 2500 cps.

Audio Power Output

At least 150 milliwatts minimum to speaker. At least 10 milliwatts to earphone jack accessible from top panel behind a snap-type waterproof cover.

Audio Distortion

Less than 10% at 2/3 rated deviation with 1000 cycle tone.

Antenna Input Impedance

To match whip antenna or 50-ohm external antenna.

Duty Cycle

Continuous.

Current Drain

12×.008

P=E·I=0.096

Maximum current drain with 12 volt dc: Receive (no signal), 8 milliamperes; Receive, 40 milliamperes with full rated audio output. P=12×.040= 0.48W at rated audio .150W output

Table 2-2. Transistor Complement.

REFERENCE DESIGNATION	TYPE	FUNCTION
	RECEIVER SECTION	
Q101	2N3478	RF Amplifier
Q102	2N3564	1st Mixer
Q103	not assigned	
Q104	2N3564	Oscillator
Q105	2N3693	2nd Mixer
Q106	not assigned	
Q107	2N3693	1st IF Amplifier
Q108	2N3693	2nd IF Amplifier
Q109	2N3693	3rd IF Amplifier

Table 2-2. Transistor Complement. (cont'd)

REFERENCE DESIGNATION	TYPE	FUNCTION
	RECEIVER SECTION	
Q110	2N3693	4th IF Amplifier
Q111	2N3693	Limiter
Q112	2N3693	1st Audio
Q113	2N3567	2nd Audio
Q114	2N3567	Class B Audio
Q115	2N3638	Class B Audio
Q116	2N3693	Noise Amplifier
	TRANSMITTER SECTION	
Q117	2N3693	Audio Amplifier
Q118	2N3693	Clipper
Q119	2N3567	Amplifier/Integrator
Q120	2N3693	Oscillator
Q121	2N3693	Modulator
Q122	2N3693	Tripler
Q123	CH2369	Tripler
Q124	CH2369	Doubler
Q125	2N3564	1st Amplifier
Q126	2N3866	2nd Amplifier
Q127	40280	Final Amplifier

Table 2-3. Diode Complement.

REFERENCE DESIGNATION	TYPE	FUNCTION
	RECEIVER SECTION	
D101	AA119	Discriminator Diode
D102	AA119	Discriminator Diode
D103	1N34A	Noise Rectifier
D104	1N34A	Noise Rectifier
D105	1N34A	Squelch Gate
D107	TS4	Bias Regulator
D108	TS4	Bias Regulator
D109	1N34A	Test Rectifier

Table 2-3. Diode Complement. (cont'd)

REFERENCE DESIGNATION	TYPE	FUNCTION
	TRANSMITTER SECTION	
D106	AA119	Diode
	CHASSIS SECTION	
D1	1N91	External Protect Diode

Table 2-4. Fuse Complement.

REFERENCE DESIGNATION	TYPE	FUNCTION
F1	1.5 AMP, 8 AG	Power Input Circuit

Table 2-5. Crystal Specifications.

RECEIVER CRYSTAL

Description
Metal-plated quartz plate wire or spring mounted in metal holder.

Mode of Operation
Fundamental.

Correlation
Series Resonance.

Holder
a. Equivalent to Military HC-25/U Holder.
b. Holder HC-25/U is anodized or painted black in color.
c. The actual operating frequency, not the crystal frequency, is stamped on the side of the receiver oscillator crystal.
d. The frequency stamp on the receiver crystal is preceded by an "R".

Frequency Range
16.0 to 19.50 megacycles.

Operating Temperature Range
-30° to +60°C

Tolerance on Nominal Frequency
Crystal is finished at a nominal room temperature of +25°C ±3°C to ±0.002% of the specified frequency. The crystal frequency does not drift more than

Tolerance on Nominal Frequency (cont'd)

±0.002% from the frequency at 25°C as the temperature is varied from -10°C to +50°C.

Effective Series Resistance

15 ohms maximum (16.0 to 19.50 mc).

Level of Drive

Maximum level of drive 1.0 milliwatts.

PISGAH

Static Capacitance

Receiver IF = $\frac{Fc}{9} + 0.4044 = \left(\frac{146.760}{9} + 0.4044\right) = 16.711$ MHz

6 $\mu\mu f$ ±1 $\mu\mu f$

Condition of Test Holder

Grounded.

To receive the Mt Pisgah 2 meter relay

Formula - Multiplication Factor

$$F_x = \frac{Fc - 455\ KC}{9} = \frac{146.760 - 0.455kc}{9} = 16.25611$$ fundamental

Series resonant

F_x = Crystal frequency.

F_c = Carrier frequency. R 146.760 Hz

TRANSMITTER CRYSTAL

Description

Metal plated quartz plate wire or spring mounted in metal holder.

Mode of Operation

Crystal designed to operate on the fundamental thickness shear frequency of the quartz plate.

Correlation

Parallel

Crystal designed to operate into load capacitance of 32 $\mu\mu f$ ±0.5 $\mu\mu f$.

Holder

a. Equivalent to Military HC-25/U Holder.
b. Holder HC-25/U is anodized or painted black in color.
c. The actual operating frequency, not the crystal frequency, is stamped on the side of the transmitter oscillator crystal.
d. The frequency stamped on the transmitter crystal is preceded by a "T".

Frequency Range

8.0 to 10.0 megacycles.

Operating Temperature Range

-30 to +60°C

146.760

XTal x 8 = 130.0488

Hi IF 16.711

XTal $-$ 16.256

Lo IF 0.455

$$IF = \cancel{146.76}^{\,F_c} - 8(XTAL)$$

$$8\left(\frac{F_c - .455}{9}\right)$$

$$= FC - \frac{8FC + 3.64}{9}$$

$$IF = FC - \tfrac{8}{9}FC + 0.40444$$

$$= \frac{FC}{9} + .40444 = \frac{146.760}{9} + .4044 = 16.711$$

IF = 16-20

RF 150-170

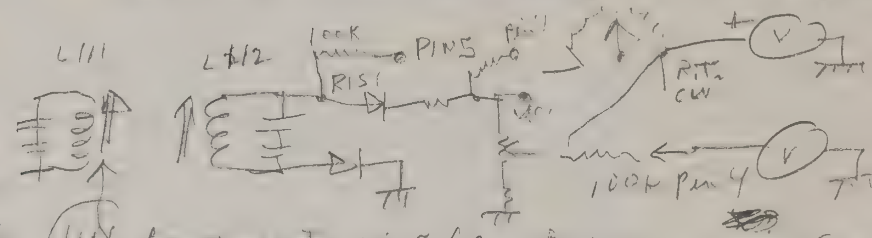
$$\frac{146.52}{9} + 0.4044 = 16.684$$

11/2$\frac{5}{6}$/77

FM1 alignment

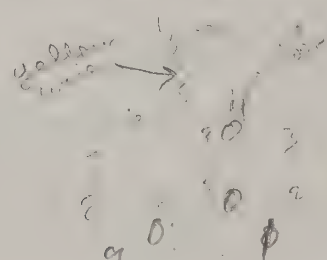
1. Put 455 KC -||- to front end of 455 Kc filter,
2. Put 0.25 V volt meter Volume control to gnd (Test plug Pin 4 to gnd)

3.



A Peak (L111) for max at pin 5 (Peak for to 455 KC Tank (14 μA)

B Peak L112 for 3 mV at Volume control (at pin 4)



TOP VIEW, Test Socket

4. ~~Set~~ XTal osc tune for max amplitude (L125) ~~125~~ 105
Test socket pin 7 (20 μA)
5. Net XTal (using 146.52 or other freq standard), (L105)
for zero discriminator volts at Test socket pin 4
6. Reduce Signal (146.52 MHz) to weak sig (use 50Ω dummy ant for RF alignment)
Then align IF, mix, RF harmonic

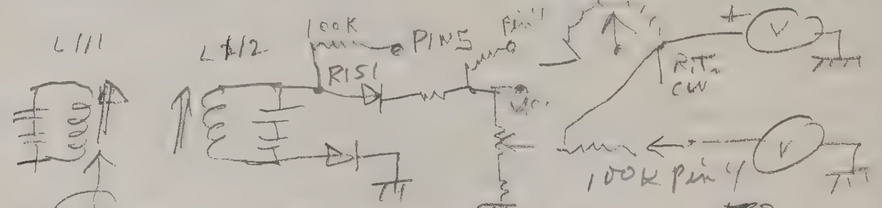
11/25/77

FM1 alignment

1. Put 455 KC ⊣⊢ to front end of 455KC filter,

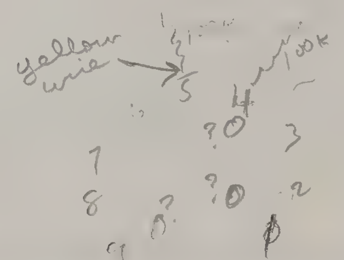
2. Put 0.25 V voltmeter Volume control to gnd (Test plug Pin 4 to gnd)

3.



A Peak L111 for max at pin 5 (Peak first on 455KC tank (14 μA)

B Peak L112 for zero V at Volume control (or pin 4)



TOP View, Test Socket

4. XTal osc tune for max amplitude (L125) ~~125~~ 105
Test socket pin 7 (20 μA)

5. Net XTal (using 146.52 or other freq standard, (L105)
for zero discriminator volts at Test socket pin 4

6. Produce signal (146.52 MHz) to work reg
(use 50Ω dummy ant for RF alignment)
then align IF, mix, RF harmonic

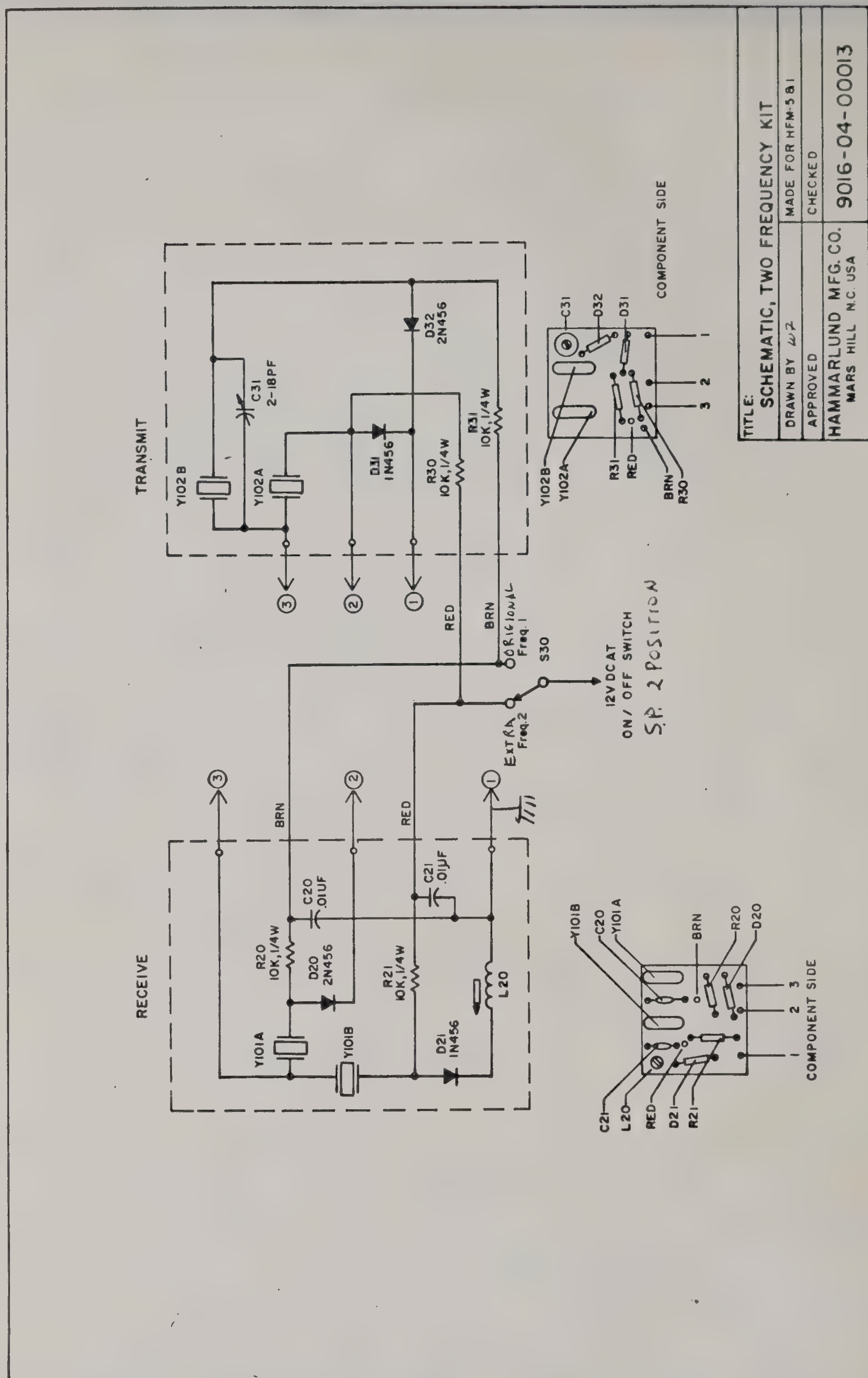


Figure 8-1. Two-Frequency Kit Schematic Diagram

Table 2-5. Crystal Specifications. (cont'd)

Tolerance on Nominal Frequency

Crystal is finished to ±0.0020% of the exact frequency required at a nominal room temperature of +25°C. Crystal unit uses an AT cut blank and does not exceed a frequency drift ±0.0020% of frequency at 25°C, ±3°C from -30°C to +60°C.

Effective Series Resistance

35 ohms over frequency range.

Level of Drive

One milliwatt over frequency range.

Static Capacitance

4 to 6 $\mu\mu f$

Condition of Testing

Holder grounded.

To Xmit to the
MT. Pisgah 2 meter relay

Formula - Multiplication Factor

$$F_x = \frac{Fc}{18} =$$

$\frac{146.160}{18.} = 8.120 \text{ MHz}$

F_x = Crystal frequency. 8.120 MHz fundamental, parallel resonant 32 pf load

F_c = Carrier frequency. T 146.160 Hz

Rec IF = $\frac{F_{carrier}}{9} \pm \frac{8}{9} \cdot 0.455 = \frac{146.76}{9} \pm \underbrace{\frac{8}{9} \cdot 0.455}_{0.404444} = 16.7111$ check:

Check IF = xtal + 0.455 = 16.2561 + 0.455 = 16.7

SECTION III

INSTALLATION AND ALIGNMENT PROCEDURES

3-1 UNPACKING

3-2 The equipment may be shipped in either export or domestic packing cases. In either event, no special unpacking procedures are necessary. When new equipment is received, select a location where the cases may be unpacked without exposure to the elements.

3-3 PRELIMINARY PROCEDURES

3-4 To prepare the equipment for use, perform the following steps:

1. Inspect equipment for any possible damage incurred in shipment. Report damage to responsible personnel immediately.

CAUTION

Do not attempt to place damaged equipment in operation as it may further impair the instrument.

2. See Figure 3-1 for the location of crystals Y101, or their sockets in the event crystals are not installed. Crystals for the receiver section are identified with the channel frequency and the letter "R" on top of the crystal case. DO NOT ATTEMPT TO USE CRYSTALS WITH OTHER MARKINGS UNLESS CRYSTAL FREQUENCY AND MODE OF OPERATION ARE KNOWN. Crystals for the transmitter section are identified with the channel frequency and the letter "T" on the top of the crystal case. DO NOT ATTEMPT TO USE CRYSTALS WITH OTHER MARKINGS, UNLESS CRYSTAL FREQUENCY AND MODE OF OPERATION ARE KNOWN. Crystals used in the transmitter section are operated in their fundamental mode. The transceiver is normally shipped with crystals installed and prealigned for these frequencies. In the event crystals are not installed, or it is necessary to change frequency of operation, obtain the desired crystals and insert firmly in sockets. Refer to Table 2-5 for crystal specifications.

3. Remove the end plate and insert eight 1.5 volt D cells as shown on transceiver labeling.

4. Replace the end plate and connect the standard whip antenna.

5. Turn the volume control fully on (clockwise). A loud hissing noise should be apparent. If there is no hiss, lift the squelch control spring loaded cover and with a screwdriver, turn the squelch control until the hiss is audible. Next, turn the volume control to the half-on position and set the squelch control until receiver hiss is only just quieted. Do not exceed this point or a large signal will be required to open the squelch again. The transceiver is now ready for operation. A more sensitive

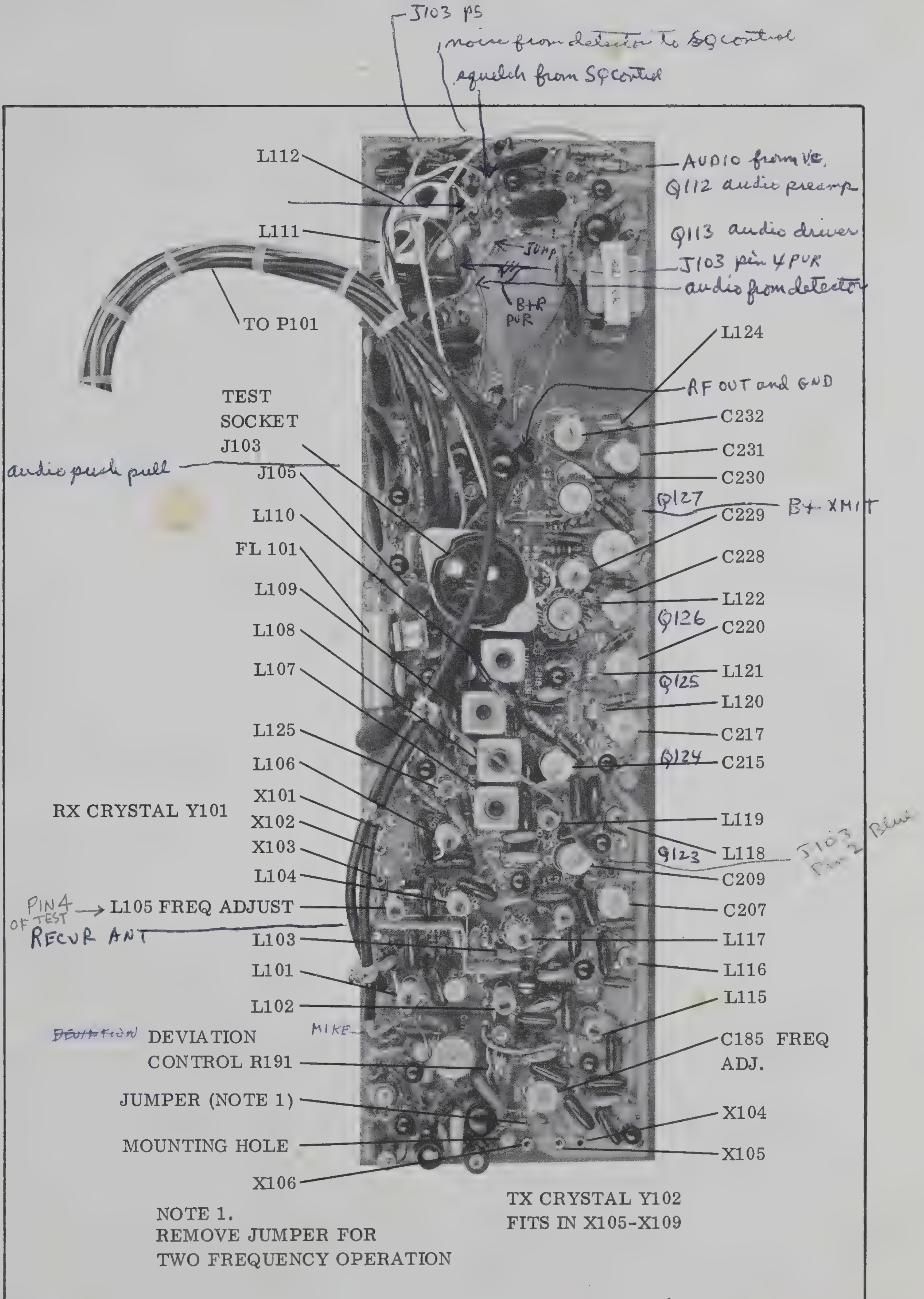


Figure 3-1. Circuit Board Assembly.

squelch setting may be obtained by setting the gain control to the desired listening level before the squelch control is adjusted.

3-5 The above directions assume that the transceiver has been adjusted at the factory, and is on the correct frequency. If alignment or frequency adjustments are required these may be carried out according to the directions in paragraph 3-15.

3-6 STANDARD WHIP ANTENNA

3-7 The standard whip antenna is normally used with the FM-1. Only one antenna length is used regardless of frequency. Consequently, best results are obtained if transmitter output circuits are tuned to the antenna. After the transmitter has been aligned into a dummy load as described in paragraph 3-15, the standard whip antenna should be connected. A field strength meter should next be set up at a convenient distance from the instrument, and capacitors, C230, C231 and C232 adjusted for maximum output as determined by the field strength meter. Best operation is always obtained when the FM-1 is held in a vertical plane. This is particularly true when the signals are weak. Even if the unit is held only a few degrees off vertical when receiving a weak signal, the signal may completely fall out and the squelch close.

3-8 The FM-1 should preferably always be operated in the clear, away from buildings, iron structures and trees. Buildings, tree plantations, and jungle will seriously absorb both transmitted and received signals. Wet foliage especially will considerably reduce the working range of the FM-1 equipment.

3-9 TACTICAL ANTENNA

3-10 The tactical antenna, when used with the FM-1, will increase the ground wave signal at the expense of the sky wave signal. The tactical antenna should be used only for ground-to-ground contacts and not for air-to-ground contacts. As with the standard whip antenna, best results will be obtained if the transmitter output circuits are tuned into the antenna with the aid of a field strength meter.

3-11 MOBILE ANTENNA

3-12 The mobile antenna may also be used with the FM-1. Due to the increased ground plane area, antenna efficiency will be increased and consequently, a greater range will be obtained. As with the standard whip antenna, best results will be obtained if the transmitter output circuits are tuned with the antenna with the aid of a field strength meter.

3-13 THE FM-1 AS A BASE STATION

3-14 The FM-1 may also be used as a base station in conjunction with the ground plane antenna. The ground plane antenna should be located as high as possible. As VHF communication is primarily line-of-sight, every effort should be made to allow the two antennas to "see" each other. This condition will allow the best possible communication between the two stations. As with the standard whip antenna, best results are obtained if transmitter output circuits are tuned to the antenna with the aid of a field strength meter.

3-15 ALIGNMENT PROCEDURES

3-16 There are several alignment procedures which may be followed. The simplest of these is described in paragraphs 3-17 and 3-19. Test equipment required for alignment consists of: a 50 microampere meter; a signal generator covering the range 455 kc, the IF frequencies 16 mc to 20 mc, and the input frequencies 150 mc to 172 mc; a frequency meter or counter; a wattmeter; and a deviation monitor.

3-17 RECEIVER ALIGNMENT

3-18 To align the receiver, proceed as follows (see Figure 3-2):

1. With the 50 μamp meter connected to pin 5 of test socket (J-103), connect signal generator at 455 kc to input of FL101 at approximately 100 μv. Peak L111 for maximum (100 μv provides 20 db). Feed generator through 0.01 μf and 3.3K ohm resistances in series.

2. With 50 μamp meter connected to pin 4 of test socket, adjust L112 for zero output.

3. With 50 μamp meter connected to pin 5 of test socket and signal generator (through 0.01 μf capacitance) to base of Q102, feed in a signal at crystal frequency plus 455 kc at the lowest possible level to start an upward swing in the 50 uamp meter (13 μv provides 20 db of quieting, approximately 15 μamps). Adjust L107, L108, L109 and L110 for maximum. At the same time, reduce generator output to lowest possible level to prevent overload.

4. With 50 μamp meter at pin 7 of test socket, peak oscillator coil L125 for maximum (approximately 25 μamps).

5. Using Counter, adjust L105 to crystal frequency.

6. With 50 μamp meter connected to pin 5 of test socket, and signal generator set at receive frequency and connected to antenna, feed in signal at lowest possible level to start an upward swing in 50 μamp meter. Adjust L101, L102, L103, L104 and L106 for maximum, at the same time reducing signal generator to lowest possible level (approximately 0.3 - 0.5 μv provides 20 db of quieting).

7. Finally, touch up L101 through L104, L107 through L110 for maximum quieting in speaker.

3-19 TRANSMITTER ALIGNMENT

3-20 To align the transmitter, proceed as follows:

1. Connect positive lead of 50 μamp meter to chassis, and negative lead to test socket (J-103).

2. Connect wattmeter and 50 ohm load to antenna jack (J4).

3. With 50 μamp meter at pin 2 of test socket, adjust L116, L117, C207, and C209 for maximum reading. Typical readings should be between 10 and 15 μamps.

4. With meter at pin 3 of the test

socket, peak L118, L119 and C215 for a maximum reading. Typical readings should be between 35 and 40 μamps.

5. With meter at pin 6 of the test socket, adjust C217, C220, C228 and C229 back and forth for maximum reading. Typical readings should be between 20 and 30 μamps.

6. Tune C230, C231, C232 for maximum power out.

7. Repeat steps 3, 4 and 5 for maximum power out.

8. Adjust L115 for best recovered audio in a standard receiver or a deviation monitor.

9. Using frequency meter or counter, adjust C185 for channel frequency and repeat above steps if necessary.

10. Set deviation by adjusting deviation control R191 until correct deviation is shown on the monitor.

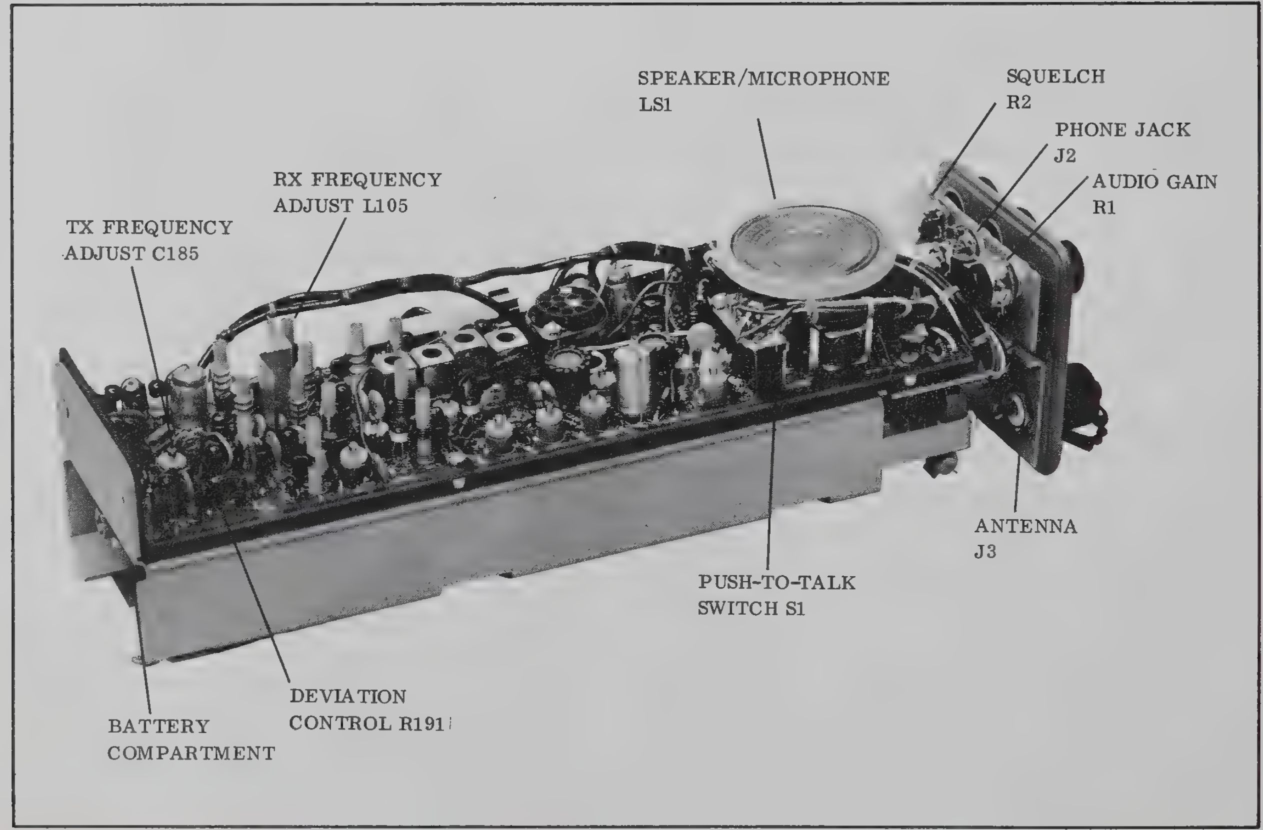


Figure 3-2. Model FM-1 Adjustments and Features

SECTION IV

OPERATION

4-1 GENERAL

4-2 This section describes how to operate the Model FM-1 transceiver. Proper operation of the instrument is predicated upon it being installed and aligned in accordance with instructions in this manual.

4-3 OPERATING CONTROLS (Figure 4-1)

4-4 STARTING AND STOPPING. The equipment is in operation when the OFF/ VOLUME control is in the ON position. Volume is increased by turning the control in a clockwise direction. The transceiver is turned OFF when the OFF/ VOLUME control is turned fully counter-clockwise. A pronounced click will indicate when the OFF position has been reached. The operator should be careful to avoid turning the control beyond the OFF position to prevent damage to the control.

4-5 SQUELCH. The squelch control, which is located behind the spring loaded cover, is preset prior to operation (paragraph 3-4, step 5) to set the level of squelch action. To adjust, the cover is lifted and the control turned until the hiss in the receiver just disappears. The squelch control should not be rotated beyond this point. The squelch circuit enables the receiver audio to be switched off in the absence of signal. The closer the control is set to the break point, the smaller the signal required to open it. The squelch control is normally set with the volume control at the normal listening level.

4-6 ANTENNA SOCKET. The standard whip antenna is connected to the antenna socket. Alternatively, the tactical antenna, the mobile antenna or the ground plane antenna are connected to the antenna socket.

4-7 PHONE JACK. The phone jack is located behind the jack cover labelled PHONE. When the head phone jack is plugged in the speaker is automatically disconnected.

4-8 EXTERNAL BATTERY JACK. The external battery cable is plugged into the external battery jack which is located under the jack cover labelled EXT BAT. The external battery source is used in fixed or mobile operation. The internal circuitry includes a diode to prevent damage to the transceiver if the battery leads are inadvertently incorrectly polarized.

4-9 PUSH-TO-TALK SWITCH. The push-to-talk switch is located on the side of the transceiver, and is normally depressed with the fingers of the left hand. When the switch is pressed, the transceiver is placed into the transmit condition and the panel controls are rendered inoperative. The operator should speak across the mouthpiece with the mouthpiece nearly touching the lips. Speaking directly into the mouthpiece will cause blasting in the receiver.

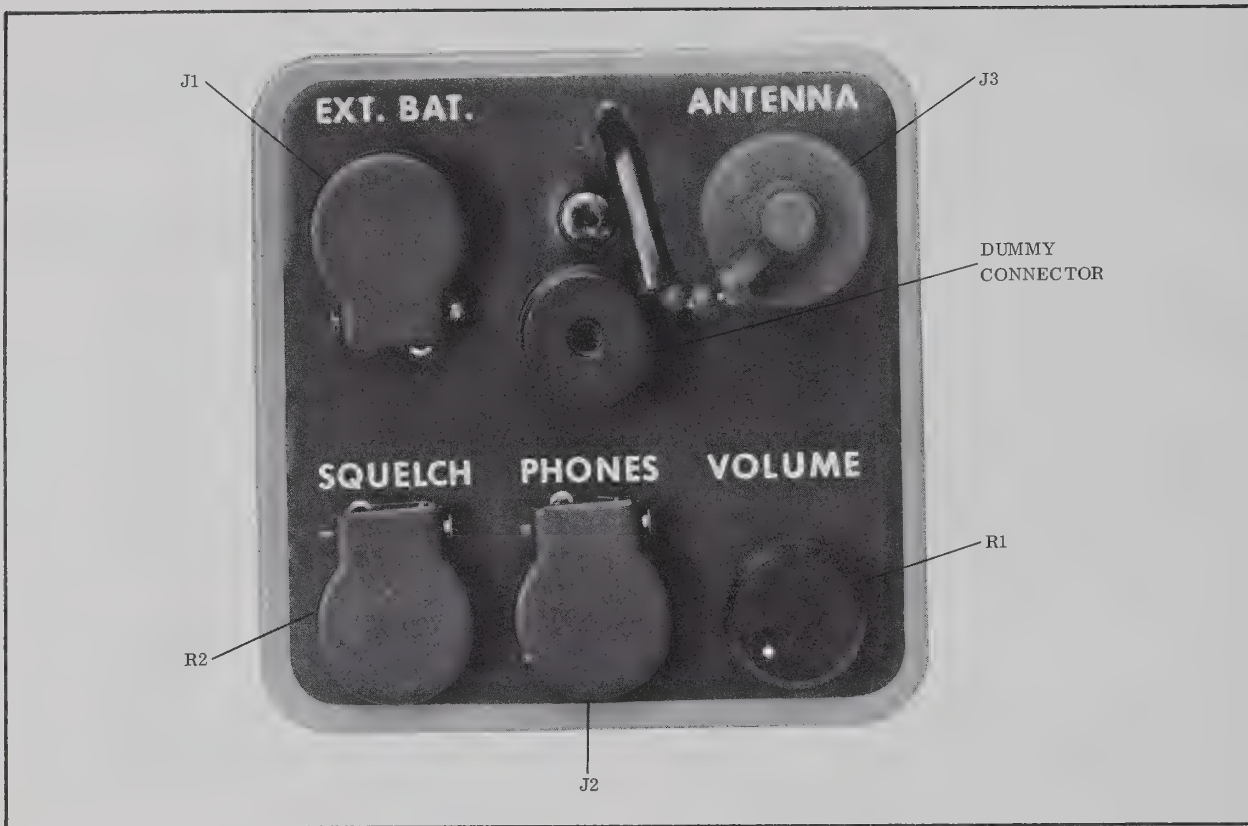


Figure 4-1. Operating Controls.

SECTION V

PREVENTIVE AND CORRECTIVE MAINTENANCE

5-1 GENERAL

5-2 This section describes the basic principles of operation for the Model FM-1, and offers maintenance information to assist the technician in troubleshooting and repairing certain malfunctions which could occur.

5-3 THEORY OF OPERATION

5-4 The FM-1 transceiver is comprised of a receiver and a transmitter (see Figure 5-1). The speaker of the receiver is used as a microphone in the transmit mode of operation.

5-5 RECEIVER CIRCUITS. The receiver is a double conversion superheterodyne in which one oscillator serves as both the first and the second source of injection voltages. All transistors in the receiver are silicon. Silicon transistors are relatively free from breakdown due to overload from adjacent transmitters, and are able to be operated under conditions of considerable heat.

5-6 The RF amplifier Q101 is operated in the common emitter mode; its dc path is in series with the local oscillator, Q104. The RF input circuit consists of L101, C101 and C102. The two capacitors form a capacitive divider providing an impedance match to Q101. Output from the RF amplifier is fed to bandpass coupler L101 and L103. Output from L103 is fed by means of an inductive tap on L103 to the first mixer Q102; for dc, Q102 is in series with Q105, the second mixer.

5-7 Following the first mixer are four tuned circuits, L107 through L110. Output from L110 is inductively coupled to the second mixer Q105. These circuits offer a high degree of selectivity to unwanted signals. The first IF frequency may be determined through the following relationship:

$$F = (F_c - 8)\ F_x$$

where F_c = carrier frequency

F_x = crystal frequency

5-8 Local oscillator Q104 operates in the fundamental series mode. The oscillator is a simple feedback type with feedback being obtained through a small winding over the main tuned circuit which consists of L125 and the associated capacitor C113. Crystal Y101 is in series with the feedback loop, representing a high impedance to all frequencies except that of the crystal. Inductor L105 "pulls" the crystal, allowing considerable adjustment of the frequency.

5-9 Capacitor C113 has a twofold purpose; to tune inductor L125 to the crystal frequency, and to pass on harmonics of the crystal frequency to the tuned circuit L106 and C111.

5-10 Basically, the oscillator operates between 16..6 mc and 19.06 mc. Output

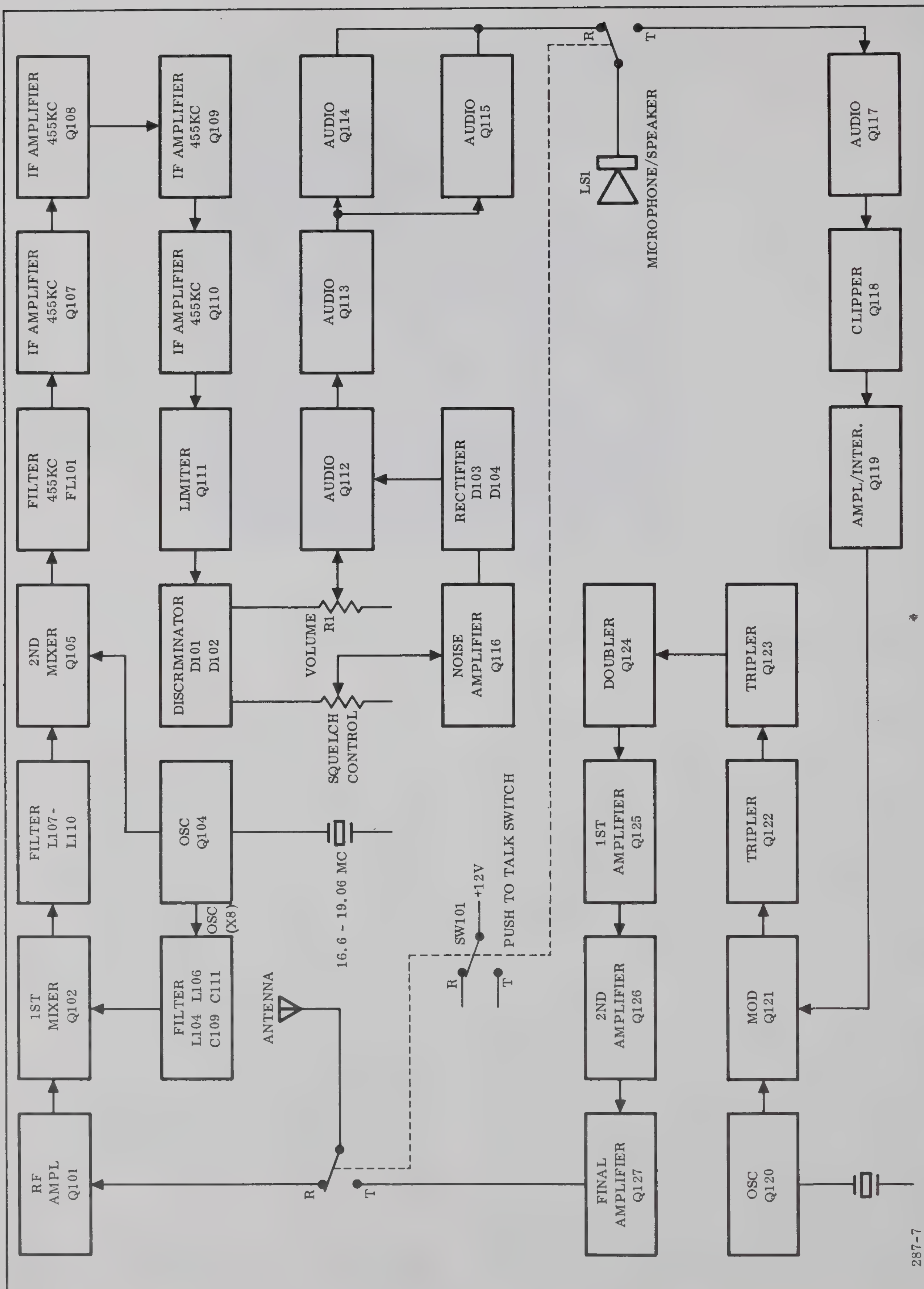


Figure 5-1. System Block Diagram.

from the oscillator is fed directly to the second mixer Q105 At the same time L106 and C111 selects the eighth harmonic of the oscillator. Tuned circuit L104 and C109 together with L106 and C111 form a highly selective bandpass coupler to remove the unwanted harmonics, and the output is fed to the first mixer, Q102. In aligning the receiver, care must be exercised to see that only the eighth harmonic is used. It is a simple matter to tune the oscillator to the tenth harmonic and allow an input signal only 910 kc away from the wanted signal.

5-11 It should be realized that with this system, the high frequency IF system L107 through L110 must be retuned each time the input circuits are tuned to a new frequency.

5-12 Following the second mixer is a highly selective ceramic filter, FL101. This filter requires no alignment, and remains permanently tuned to the center frequency of 455 kc.

5-13 Transistors Q107 through Q110 are resistance-coupled IF amplifiers. Due to the extremely good selectivity obtained from filter FL101, further selectivity is not required. Each of the amplifiers are series connected for dc. Some limiting action takes place in the IF amplifier, especially the latter stages on larger signals. However, limiting is mainly effected by Q111. The limiter transformer L111 is link coupled to discriminator transformer L112, and from there the output is fed to diodes D101 and D102. A de-emphasis network consisting of R150 and C157 connects the discriminator output to the first audio amplifier Q112 through volume control R3.

5-14 Simultaneously, output from the discriminator is fed to the noise amplifier Q116 through C165 and squelch control R2. The noise amplifier is designed to pass only noise, all audio signal being removed by a combination of negative feedback and small coupling capacitors. The output is rectified by D103 and D104 and the resultant dc fed by the diode gate D105 to the first audio transistor, Q112.

5-15 Under the no-signal condition the rectified noise voltage causes amplifier Q112 to be saturated and the voltage at the collector of Q112 to be at or near zero, causing the next amplifier stage Q113 to cut off. The presence of a signal however causes a drop in noise and a reduction in the dc bias fed through diode gate D105. The diode gate opens and direct-coupled amplifier Q112 and Q113 is allowed to normally operate, allowing the signal to reach the speaker.

5-16 The class B audio amplifiers Q114 and Q115 are series connected for dc (that is, each transistor has 6 volts across it from collector to emitter). However, from an ac point of view the two transistors are in parallel. The upper transistor (Q114) is an NPN and the lower transistor (Q115) is a PNP. When the incoming signal is positive going only the NPN transistor conducts, and when the incoming signal is negative only the PNP transistor conducts. The two diodes D107 and D108 are part of the forward bias network consisting of R170 and R172. The two diodes allow the bias to be automatically adjusting under varying voltage and temperature conditions.

5-17 TRANSMITTER CIRCUITS. Q120 is a parallel mode Colpitts oscillator operating in the fundamental mode. Out-

put is multiplied eighteen times before reaching the antenna. Output from the oscillator is capacitance coupled to modulator Q121, and then to the first tripler stage, Q122, and to a bandpass stage consisting of L116/C198 and L117, C207, C208, C209, C210. A further tripler stage, Q123, is followed by bandpass coupler L118, C211, L119 and the associated capacitors C214 and C215. The bandpass couplers remove unwanted harmonics of the crystal oscillator, passing only the wanted signal. A doubler stage, Q124, converts the signal to the wanted frequency, ready for amplification by amplifiers Q125, Q126, and Q127. A double pi output network removes unwanted harmonics from the output signal and allows a proper match between transistor Q127 and the antenna.

5-18 All stages following the modulator operate approximately class C. In the absence of drive these stages draw no current.

5-19 MODULATOR CIRCUITS. In the transmit mode, speaker LS1 serves a dual function as the microphone. The components C171 and R175 form a preemphasis network. This is followed by an audio amplifier Q117 direct coupled to a clipper, Q118. Following the clipper is a low pass filter comprised of L114, C182, R187, and C178, the purpose of which is to remove the audio harmonics generated in the clipper. The amplifier-integrator stage de-emphasizes the signal. Output from the integrator on signals which have been clipped are triangle shaped. These signals are now fed, through the deviation control, to modulator Q121. The deviation control sets the deviation of the modulator. Too great a deviation will cause sidebands to fall outside the receiver pass band at the receiving end, causing the signal to be very distorted.

5-20 CONTROL CIRCUITS

5-21 When the push-to-talk switch is depressed, the following functions take place: (1) the antenna is changed from the receiver to the transmitter, (2) the speaker is removed from the receiver and connected to the input of Q117, allowing its use as a microphone, and (3) the +12 volts is removed from the receiver and connected to the transmitter.

5-22 TEST POINTS

5-23 Various test points have been provided in the Model FM-1, and the outputs connected to test socket J103. Diode D106 rectifies a portion of the oscillator voltage, thus the oscillator is merely adjusted for maximum dc voltage at the test socket, pin 7. Diode D109, likewise, feeds a rectified signal to the test socket, enabling the various transmitter stages to be tuned for maximum output. A list of test points in the instrument is provided in Table 5-1.

5-24 CORRECTIVE MAINTENANCE

5-25 TROUBLE SHOOTING. In trouble shooting the Model FM-1, a step-by-step method is helpful. Isolate the fault by working back from the speaker until the defective stage is found. When trouble shooting the receiver it is well to remember that most of the stages are operated in series for dc, in order to keep the battery current consumption at a minimum. Consequently, a defect in one stage may well affect several other stages. Voltage measurements should

Table 5-1. Test Points

Test Point	Function
1.	-
2.	Transmitter second tripler current.
3.	Transmitter doubler current.
4.	Receiver discriminator.
5.	Receiver limiter output.
6.	Transmitter final drive.
7.	Receiver oscillator output.
8.	Battery voltage.
9.	Receiver audio output.
10.	-
11.	Ground.
12.	Transmitter audio input.
13.	-
14.	Transmitter control.

only be made with a VTVM (except where measured at the test socket). The low resistance of ordinary multimeters may well upset the voltage measurements, especially in the higher impedance circuits. Tables 5-2 and 5-3 provide a list of typical voltage measurements.

CAUTION

When aligning the transmitter, it is possible to tune some of the circuits to the incorrect harmonic. For example, the first tripler stage may also be made to double. An absorbsion type wavemeter should be used to check the frequency when doubt occurs.

5-26 PARTS REPLACEMENT AND ALIGNMENT. When replacing components which are connected to or operate in conjunction with one or more of the tuned circuits, a realignment of the repaired section should be made. Alignment procedures are fully covered in Section III, paragraph 3-15. Every effort has been made to use standard components wherever possible to make replacement of parts noncritical. Components are listed by part number and reference designation in Section VI of this handbook.

5-27 When replacing components, care should be used not to damage them through the use of excessive heat. Although silicon transistors are used throughout, even these can be damaged if too much heat is applied for too long a period. Likewise, resistors and capacitors are damaged or change value when excessive heat is applied. When replacing components on the printed circuit board, a solder sucker should be used to withdraw the solder from eyeletted holes.

Table 5-2. Receiver Voltage Measurements.

		Base	Emitter	Collector
RF Amp	Q101	1.3v	0.75	4.2
1st Mixer	Q102	1.0	0.3	4.0
Oscillator	Q104	4.0	5.6	12.0
2nd Mixer	Q105	6.8	6.2	8.5
With Noise				
1st IF	Q107	1.0	0.4	1.6
2nd IF	Q108	3.6	3.0	4.5
3rd IF	Q109	6.5	5.9	7.2
4th IF	Q110	9.2	8.6	10.0
Limiter	Q111	5.7	5.6	11.0
With 0.1 μf from Filter Output to Ground				
	Q107	1.0	0.4	1.6
	Q108	3.6	3.0	4.5
	Q109	6.5	5.9	7.2
	Q110	9.3	8.7	10.0
	Q111	4.8	4.6	11.5
Unsquelched with Noise				
1st Audio	Q112	0.63	0.0	2.2
Audio Driver	Q113	2.2	1.6	11.0
Audio Out	Q114	6.3	5.7	12.0
Audio Out	Q115	5.1	5.7	0.0
Noise Amp	Q116	1.1	0.4	2.7
Squelched				
	Q112	0.65	0.0	0.2
	Q113	0.2	0.0	12.0
	Q114	6.5	5.9	12.0
	Q115	5.4	0.6	0.0
	Q116	1.1	0.5	2.7

1. All measurements are referenced to ground.
2. Input Voltage: 12 vdc.
3. Test Equipment: Hewlett-Packard Model No. 410B VTVM.

Table 5-3. Transmitter Voltage Measurements.

DC VOLTAGE			
Transistor	Emitter	Base	Collector
Q117	0.6	1.3	11.0
Q118	3.6	4.2	6.6
Q119	0.3	0.9	4.2
Q120	6.0	8.0	11.0
Q121	1.2	0.4	11.0
Q122	0.3	0.4	11.0
Q123	0.0	1.0	11.0
Q124	0.0	0.4	6.0
Q125	0.0	0.0	8.8
Q126	0.0	0.0	10.0
Q127	0.0	0.0	11.0
AC VOLTAGE			
Q120	3.9	4.2	0.0
Q121	0.4	1.4	1.5
Q122	0.2	1.5	4.2
Q123	0.2	1.2	2.6
Q124	0.6	1.2	3.0
Q125	0.8	1.4	5.8
Q126	1.5	3.0	8.0
Q127	0.5	2.4	9.5

1. Input Voltage: 12 vdc.
2. Test Equipment: Hewlett Packard Model No. 410B VTVM.

SECTION VI

PARTS LIST

6-1 GENERAL

6-2 This section of the handbook contains a list of replaceable parts for the Model FM-1 transceiver, and the accessory items described in Section VII. The parts list is arranged as follows: pages 6-2 through 6-17 cover the FM-1 unit, pages 6-18 through 6-20 cover the RP-1 repeater, and the balance of the parts list catalogs components of the two-frequency kit and the high gain tactical antenna.

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY PER ASSY	MANUFACTURER
PRINTED CIRCUIT BOARD ASSEMBLY				
C101	M1519-01-00084	Capacitor, Dur Mica, 15 pf	1	El Menco
C102	MI519-01-00096	Capacitor, Dur Mica, 36 pf	1	El Menco
C103	MI509-01-01019	Capacitor, Disc Ceramic, 0.001 μf	1	R. M. C.
C104	MI509-01-01019	Capacitor, Disc Ceramic, 0.001 μf	1	R. M. C.
C105	MI509-02-04001	Capacitor, Tubular Ceramic, 1.0 pf	1	Erie
C106	MI509-01-01042	Capacitor, Disc Ceramic 0.01 μf	1	R. M. C.
C107	MI509-01-01019	Capacitor, Disc Ceramic 0.001 μf	1	R. M. C.
C108	MI509-01-01019	Capacitor, Disc Ceramic 0.001 μf	1	R. M. C.
C109	MI519-01-00059	Capacitor, Dur Mica, 20 pf	1	El Menco
C110	MI509-02-04001	Capacitor, Tubular Ceramic, 1.0 pf	1	Erie
C111	MI519-01-00084	Capacitor, Dur Mica, 15 pf	1	El Menco
C112				
C113	MI519-01-00084	Capacitor, Dur Mica, 15 pf	1	El Menco
C114				
C115	MI509-01-01019	Capacitor, Disc Ceramic, 0.001 μf	1	R. M. C.
C116	MI509-01-01042	Capacitor, Disc Ceramic, 0.01 μf	1	R. M. C.
C117	MI519-01-00023	Capacitor, Dur Mica, 1 pf	1	El Menco
C118	MI509-01-01043	Capacitor, Disc Ceramic, 0.1 μf, 25 v	1	R. M. C.
C119	MI519-01-00023	Capacitor, Dur Mica 1.0 pf	1	El Menco
C120	MI509-01-01042	Capacitor, Disc Ceramic, 0.01 μf	1	R. M. C.
C121	MI509-01-01042	Capacitor, Disc Ceramic, 0.01 μf	1	R. M. C.
C122	MI519-01-00084	Capacitor, Dur Mica, 15 pf	1	El Menco
C123	MI509-01-01042	Capacitor, Disc Ceramic, 0.01 μf	1	R. M. C.
C124	MI519-01-00023	Capacitor, Dur Mica, 1.0 pf	1	El Menco

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY PER ASSY	MANUFACTURER
PRINTED CIRCUIT BOARD ASSEMBLY (Cont'd)				
C125				
C126	MI519-01-00023	Capacitor, Dur Mica, 1 pf	1	El Menco
C127				
C128				
C129				
C130				
C131	MI509-01-01042	Capacitor, Disc Ceramic, 0.01 μf	1	R. M. C.
C132	MI509-01-01042	Capacitor, Disc Ceramic, 0.01 μf	1	R. M. C.
C133	MI509-01-01042	Capacitor, Disc Ceramic, 0.01 μf	1	R. M. C.
C134	MI509-01-01042	Capacitor, Disc Ceramic, 0.01 μf	1	R. M. C.
C135	MI509-01-01043	Capacitor, Disc Ceramic, 0.1 μf 25 v	1	R. M. C.
C136	MI509-01-01042	Capacitor, Disc Ceramic, 0.01 μf	1	R. M. C.
C137	MI509-01-01043	Capacitor, Disc Ceramic, 0.1 μf 25 v	1	R. M. C.
C138	MI509-01-01042	Capacitor, Disc Ceramic, 0.01 μf	1	R. M. C.
C139	MI509-01-01043	Capacitor, Disc Ceramic, 0.1 μf 25 v	1	R. M. C.
C140	MI509-01-01042	Capacitor, Disc Ceramic, 0.01 μf	1	R. M. C.
C141	MI519-01-00049	Capacitor, Dur Mica, 12 pf	1	El Menco
C142	MI519-01-00049	Capacitor, Dur Mica, 12 pf	1	El Menco
C143	MI509-01-01043	Capacitor, Disc Ceramic, 0.1 μf 25 v	1	R. M. C.
C144	MI509-01-01019	Capacitor, Disc Ceramic, 0.001 μf	1	R. M. C.
C145	MI509-01-01042	Capacitor, Disc Ceramic, 0.01 μf	1	R. M. C.
C146	MI509-01-01043	Capacitor, Disc Ceramic, 0.1 μf 25 v	1	R. M. C.
C147	MI509-01-01043	Capacitor, Disc Ceramic, 0.1 μf 25 v	1	R. M. C.
C148	MI509-01-01042	Capacitor, Disc Ceramic, 0.01 μf	1	R. M. C.

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY PER ASSY	MANUFACTURER
PRINTED CIRCUIT BOARD ASSEMBLY (Cont'd)				
C149	MI509-01-01043	Capacitor, Disc Ceramic, 0.1 μf 25 v	1	R. M. C.
C150	MI509-01-01043	Capacitor, Disc Ceramic, 0.1 μf 25 v	1	R. M. C.
C151	MI519-01-00097	Capacitor, Dur Mica, 620 pf	1	El Menco
C152	MI519-01-00097	Capacitor, Dur Mica, 620 pf	1	El Menco
C153	MI509-01-01043	Capacitor, Disc Ceramic, 0.1 μf 25 v	1	R. M. C.
C154	MI519-02-00069	Capacitor, Dur Mica, 820 pf	1	El Menco
C155	MI519-02-00069	Capacitor, Dur Mica, 820 pf	1	El Menco
C156	MI509-01-01020	Capacitor, Disc Ceramic, 0.005 μf	1	R. M. C.
C157	MI528-01-03002	Capacitor, Flat Foil, 0.047 μf	1	Amperex
C158				
C159	MI509-01-01043	Capacitor, Disc Ceramic, 0.1 μf 25 v	1	R. M. C.
C160	MI509-01-01043	Capacitor, Disc Ceramic, 0.1 μf 25 v	1	R. M. C.
C161	MI515-02-04012	Capacitor, Electrolytic, 4 μf 10 v	1	Amperex
C162	K1528-01-03004	Capacitor, Flat Foil, 0.022 μf	1	Amperex
C163	K1515-02-04012	Capacitor, Electrolytic, 4 μf 10 v	1	Amperex
C164	MI509-01-01019	Capacitor, Disc Ceramic, 0.001 μf	1	R. M. C.
C165	M1509-01-01020	Capacitor, Disc Ceramic, 0.005 μf	1	R. M. C.
C166	K1515-02-04012	Capacitor, Electrolytic, 4 μf 10 v	1	Amperex
C167	K1515-02-04012	Capacitor, Electrolytic, 4 μf 10 v	1	Amperex
C168	K1515-02-04015	Capacitor, Electrolytic, 40 μf 16 v	1	Amperex
C169	M1509-01-01019	Capacitor, Disc Ceramic, 0.001 μf	1	R. M. C.
C170	K1515-02-04001	Capacitor, Electrolytic, 6.4 μf 16 v	1	Amperex
C171	K1528-01-03001	Capacitor, Flat Foil, 0.033 μf	1	Amperex
C172	M1509-01-01042	Capacitor, Disc Ceramic, 0.01 μf	.1	R. M. C.

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY PER ASSY	MANUFACTURER
PRINTED CIRCUIT BOARD ASSEMBLY (Cont'd)				
C173	M1509-01-01042	Capacitor, Disc Ceramic, 0.01 μf	1	R. M. C.
C174	K1515-02-04014	Capacitor, Electrolytic, 20 μf 16 v	1	Amperex
C175	K1515-02-04016	Capacitor, Electrolytic, 80 μf 25 v	1	Amperex
C176	K1515-02-04001	Capacitor, Electrolytic, 6.4 μf 16 v	1	Amperex
C177	K1515-02-04001	Capacitor, Electrolytic, 6.4 μf 16 v	1	Amperex
C178	M1528-01-03002	Capacitor, Flat Foil, 0.047 μf	1	Amperex
C179	M1528-01-03003	Capacitor, Flat Foil, 0.01 μf	1	Amperex
C180	K1515-02-04011	Capacitor, Electrolytic, 50 μf 6.4 v	1	Amperex
C181	K1515-02-04001	Capacitor, Electrolytic, 6.4 μf 16 v	1	Amperex
C182	M1509-01-01042	Capacitor, Disc Ceramic, 0.01 μf	1	R. M. C.
C183				
C184				
C185	K1543-01-00001	Capacitor, Variable, 1.5 - 8.5 μf	1	Amperex
C186				
C187	M1519-01-00087	Capacitor, Dur Mica, 56 pf	1	El Menco
C188				
C189	M1509-01-01042	Capacitor, Disc Ceramic, 0.01 μf	1	R. M. C.
C190	M1519-01-00043	Capacitor, Dur Mica, 100 pf	1	El Menco
C191	M1519-02-00074	Capacitor, Dur Mica, 25 pf	1	El Menco
C192	M1519-01-00050	Capacitor, Dur Mica, 22 pf	1	El Menco
C193	M1519-01-00086	Capacitor, Dur Mica 33 pf	1	El Menco
C194	M1509-01-01042	Capacitor, Disc Ceramic, 0.01 μf	1	R. M. C.
C195	M1509-01-01042	Capacitor, Disc Ceramic, 0.01 μf	1	R. M. C.
C196	M1519-01-00043	Capacitor, Dur Mica, 100 pf	1	El Menco

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY PER ASSY	MANUFACTURER
PRINTED CIRCUIT BOARD ASSEMBLY (Cont'd)				
C197	M1519-02-00034	Capacitor, Dur Mica, 150 pf	1	El Menco
C198	M1519-01-00042	Capacitor, Dur Mica, 47 pf	1	El Menco
C199	M1509-01-01042	Capacitor, Disc Ceramic, 0.01 μf	1	R. M. C.
C200	M1509-01-01042	Capacitor, Disc Ceramic, 0.01 μf	1	R. M. C.
C201				
C202				
C203				
C204				
C205				
C206	M1519-01-00011	Capacitor, Dur Mica, 3 pf	1	El Menco
C207	K1543-01-00002	Capacitor, Variable, 2-18 pf	1	Amperex
C208	M1519-02-00076	Capacitor, Dur Mica, 27 pf	1	El Menco
C209	K1543-01-00002	Capacitor, Variable, 2-18 pf	1	Amperex
C210	M1519-01-00088	Capacitor, Dur Mica, 82 pf	1	El Menco
C211	M1519-01-00005	Capacitor, Dur Mica, 24 pf	1	El Menco
C212	M1509-01-01042	Capacitor, Disc Ceramic, 0.01 μf	1	R. M. C.
C213	M1519-01-00011	Capacitor, Dur Mica, 3 pf	1	El Menco
C214	M1519-02-00076	Capacitor, Dur Mica, 27 pf	1	El Menco
C215	K1543-01-00002	Capacitor, Variable, 2-18 pf	1	Amperex
C216	M1509-01-01042	Capacitor, Disc Ceramic, 0.01 μf	1	R. M. C.
C217	K1543-01-00002	Capacitor, Variable, 2-18 pf	1	Amperex
C218	M1519-02-00064	Capacitor, Dur Mica, 5 pf	1	El Menco
C219	M1509-01-01042	Capacitor, Disc Ceramic, 0.01 μf	1	R. M. C.
C220	K1543-01-00002	Capacitor, Variable, 2-18 pf	1	Amperex

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY PER ASSY	MANUFACTURER
PRINTED CIRCUIT BOARD ASSEMBLY (Cont'd)				
C221				
C222				
C223				
C224	K1515-02-04016	Capacitor, Electrolytic, 80 μf 25 v	1	Amperex
C225	M1509-01-01019	Capacitor, Disc Ceramic, 0.001 μf	1	R. M. C.
C226	M1519-02-00064	Capacitor, Dur Mica, 5 pf	1	El Menco
C227	M1509-01-01042	Capacitor, Disc Ceramic, 0.01 μf	1	R. M. C.
C228	K1543-01-00002	Capacitor, Variable, 2-19 pf	1	Amperex
C229	K1543-01-00002	Capacitor, Variable, 2-18 pf	1	Amperex
C230	K1543-01-00002	Capacitor, Variable, 2-18 pf	1	Amperex
C231	K1543-01-00002	Capacitor, Variable, 2-18 pf	1	Amperex
C232	K1543-01-00001	Capacitor, Variable, 1.5 - 8.5 pf	1	Amperex
C233	M1509-01-01042	Capacitor, Disc Ceramic, 0.01 μf	1	R. M. C.
C234	M1509-01-01042	Capacitor, Disc Ceramic, 0.01 μf	1	R. M. C.
C235				
C236	M1509-01-01042	Capacitor, Disc Ceramic, 0.01 μf	1	R. M. C.
C237	M1509-01-01042	Capacitor, Disc Ceramic, 0.01 μf	1	R. M. C.
C238				
C239				
C240				
D101	AA119	Diode	1	Amperex
D102	AA119	Diode	1	Amperex
D103	1N34A	Diode	1	G. E.
D104	1N34A	Diode	1	G. E.

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY PER ASSY	MANUFACTURER
PRINTED CIRCUIT BOARD ASSEMBLY (Cont'd)				
D105	1N34A	Diode	1	G. E.
D106	AA119	Diode	1	Amperex
D107	TS4	Diode	1	Diodes, Inc.
D108	TS4	Diode	1	Diodes, Inc.
D109	1N34A	Diode	1	G. E.
D110				
D111				
FL101	K2725-01-00001	Filter, Ceramic TL30D9-57A	1	Clevite
H101	K2610-01-00001	Heat Sink	1	Wakefield
H102	K2610-01-00001	Heat Sink	1	Wakefield
J103	K2129-01-00006	Socket Meter	1	
L101	K1806-01-00070	Coil, Antenna	1	
L102	K1806-01-00071	Coil, R. F. Int.	1	
L103	K1806-01-00072	Coil, Mixer Input	1	
L104	K1806-01-00072	Coil, Multiplier Output	1	
L105	K1806-01-00061	Coil, Crystal Trimmer	1	
L106	K1806-01-00074	Coil, Multiplier Output	1	
L107	B1805-02-00205	Coil, IF	1	
L108	B1805-02-00205	Coil, IF	1	
L109	B1805-02-00205	Coil, IF	1	
L110	B1811-02-00029	Coil, IF	1	
L111	M1813-01-00001	XMFR, 455 KC Limiter	1	
L112	M1813-01-00002	Discriminator 455 KC	1	
L113	K5627-01-00010	Choke, Audio 0.5 HY	1	

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY PER ASSY	MANUFACTURER
PRINTED CIRCUIT BOARD ASSEMBLY (Cont'd)				
L114				
L115	K1806-01-00060	Coil, Phase Modulator	1	
L116	K1806-01-00059	Coil, Tripler	1	
L117	K1806-01-00059	Coil, Tripler	1	
L118	K1806-01-00045	Coil, 2nd Tripler	1	
L119	K1806-01-00045	Coil, 2nd Tripler	1	
L120	M1806-01-00052	Coil, Doubler	1	
L121	M1806-01-00053	Coil, Amplifier	1	
L122	M1806-01-00053	Coil, Amplifier	1	
L123	M1806-01-00052	Coil, Amplifier	1	
L124	M1806-01-00054	Coil, Amplifier	1	
L125	K1824-02-00002	Coil, OSC Output	1	
L126	K1804-01-00021	Coil, 15 μh	1	
L127	K1804-01-00021	Coil, 15 μh	1	
L128	K1804-01-00021	Coil, 15 μh	1	
L129	K1804-01-00021	Coil, 15 μh	1	
L130	K1805-01-00009	Coil, 3.3 μh	1	
L131	K1805-01-00009	Coil, 3.3 μh	1	
L132	K1805-01-00009	Coil, 3.3 μh	1	
L133	K1805-01-00009	Coil, 3.3 μh	1	
L134	K1806-01-00055	Coil, RFC	1	
P101	K2132-01-00009	Plug PC Board Output	1	
Q101	2N3478	Transistor, Silicon	1	RCA
Q102	2N3564	Transistor, Silicon	1	Fairchild

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY PER ASSY	MANUFACTURER
PRINTED CIRCUIT BOARD ASSEMBLY (Cont'd)				
Q103				
Q104	2N3564	Transistor, Silicon	1	Fairchild
Q105	2N3693	Transistor, Silicon	1	Fairchild
Q106				
Q107	2N3693	Transistor, Silicon	1	Fairchild
Q108	2N3693	Transistor, Silicon	1	Fairchild
Q109	2N3693	Transistor, Silicon	1	Fairchild
Q110	2N3693	Transistor, Silicon	1	Fairchild
Q111	2N3693	Transistor, Silicon	1	Fairchild
Q112	2N3693	Tranisistor, Silicon	1	Fairchild
Q113	2N3567	Transistor, Silicon	1	Fairchild
Q114	2N3567	Transistor, Silicon	1	Fairchild
Q115	2N3638	Transistor, Silicon	1	Fairchild
Q116	2N3693	Transistor, Silicon	1	Fairchild
Q117	2N3693	Transistor, Silicon	1	Fairchild
Q118	2N3693	Transistor, Silicon	1	Fairchild
Q119	2N3567	Transistor, Silicon	1	Fairchild
Q120	2N3693	Transistor, Silicon	1	Fairchild
Q121	2N3693	Transistor, Silicon	1	Fairchild
Q122	2N3693	Transistor, Silicon	1	Fairchild
Q123	CH2369	Transistor, Silicon	1	Continental Devices
Q124	CH2369	Transistor, Silicon	1	Continental Devices
Q125	2N3564	Transistor, Silicon	1	Fairchild
Q126	2N3866	Transistor, Silicon	1	RCA

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY PER ASSY	MANUFACTURER
PRINTED CIRCUIT BOARD ASSEMBLY (Cont'd)				
Q127	40280	Transistor, Silicon	1	RCA
	All Resistors Are Fixed Composition 1/4W. ±10% Unless Otherwise Specified			
R101	4K702-01-00047	Resistor, 18K	1	Moulded Ntl.
R102	K4702-01-00044	Resistor, 10K	1	Moulded Ntl.
R103	K4702-01-00028	Resistor, 470 Ohm	1	Moulded Ntl.
R104	K4702-01-00028	Resistor, 470 Ohm	1	Moulded Ntl.
R105	K4702-01-00052	Resistor, 47K	1	Moulded Ntl.
R106	K4702-01-00049	Resistor, 27K	1	Moulded Ntl.
R107	K4702-01-00038	Resistor, 470 Ohm	1	Moulded Ntl.
R108	K4702-01-00036	Resistor, 2.2K	1	Moulded Ntl.
R109				
R110	K4702-01-00048	Resistor, 22K	1	Moulded Ntl.
R111	K4702-01-00056	Resistor, 100K	1	Moulded Ntl.
R112	K4702-01-00052	Resistor, 47K	1	Moulded Ntl.
R113	K4702-01-00024	Resistor, 220 Ohm	1	Moulded Ntl.
R114	K4702-01-00038	Resistor, 3.3K	1	Moulded Ntl.
R115	K4702-01-00050	Resistor, 33K	1	Moulded Ntl.
R116				
R117	K4702-01-00037	Resistor, 2.7K	1	Moulded Ntl.
R118	K4702-01-00051	Resistor, 39K	1	Moulded Ntl.
R119	K4702-01-00049	Resistor, 27K	1	Moulded Ntl.
R120	K4702-01-00032	Resistor, 1K	1	Moulded Ntl.
R121				
R122				
R123				

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY PER ASSY	MANUFACTURER
PRINTED CIRCUIT BOARD ASSEMBLY (Cont'd)				
R124				
R125				
R126	K4702-01-00032	Resistor, 1K	1	Moulded Ntl.
R127	K4702-01-00032	Resistor, 1K	1	Moulded Ntl.
R128	K4702-01-00032	Resistor, 1K	1	Moulded Ntl.
R129	K4702-01-00056	Resistor, 100K	1	Moulded Ntl.
R130	K4702-01-00038	Resistor, 3.3K	1	Moulded Ntl.
R131	K4702-01-00056	Resistor, 100K	1	Moulded Ntl.
R132	K4702-01-00038	Resistor, 3.3K	1	Moulded Ntl.
R133	K4702-01-00056	Resistor, 100K	1	Moulded Ntl.
R134	K4702-01-00038	Resistor, 3.3K	1	Moulded Ntl.
R135	K4702-01-00056	Resistor, 100K	1	Moulded Ntl.
R136	K4702-01-00038	Resistor, 3.3K	1	Moulded Ntl.
R137	K4702-01-00032	Resistor, 1K	1	Moulded Ntl.
R138	K4702-01-00056	Resistor, 100K	1	Moulded Ntl.
R139	K4702-01-00044	Resistor, 10K	1	Moulded Ntl.
R140	K4702-01-00032	Resistor, 1K	1	Moulded Ntl.
R141				
R142				
R143				
R144				
R145				
R146	K4702-01-00028	Resistor, 470 Ohm	1	Moulded Ntl.
R147	K4702-01-00032	Resistor, 1K	1	Moulded Ntl.

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY PER ASSY	MANUFACTURER
PRINTED CIRCUIT BOARD ASSEMBLY (Cont'd)				
R148	K4702-01-00046	Resistor, 15K	1	Moulded Ntl.
R149	K4702-01-00046	Resistor, 15K	1	Moulded Ntl.
R150	K4702-01-00037	Resistor, 2.7K	1	Moulded Ntl.
R151	K4702-01-00058	Resistor, 150K	1	Moulded Ntl.
R152	K4702-01-00056	Resistor, 100K	1	Moulded Ntl.
R153				
R154				
R155				
R156				
R157	K4702-01-00050	Resistor, 33K	1	Moulded Ntl.
R158	K4702-01-00032	Resistor, 1K	1	Moulded Ntl.
R159	K4702-01-00041	Resistor, 5.6K	1	Moulded Ntl.
R160	K4702-01-00032	Resistor, 1K	1	Moulded Ntl.
R161				
R162				
R163				
R164				
R165				
R166	K4702-01-00056	Resistor, 100K	1	Moulded Ntl.
R167	K4702-01-00046	Resistor, 15K	1	Moulded Ntl.
R168				
R169	K4702-01-00020	Resistor, 100 Ohm	1	Moulded Ntl.
R170	K4702-01-00036	Resistor, 2.2K	1	Moulded Ntl.
R171				

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY PER ASSY	MANUFACTURER
PRINTED CIRCUIT BOARD ASSEMBLY (Cont'd)				
R172	K4702-01-00036	Resistor, 2.2K	1	Moulded Ntl.
R173				
R174				
R175	K4702-01-00041	Resistor, 5.6K	1	Moulded Ntl.
R176	K4702-01-00032	Resistor, 1K	1	Moulded Ntl.
R177	K4702-01-00042	Resistor, 6.8K	1	Moulded Ntl.
R178	K4702-01-00035	Resistor, 1.8K	1	Moulded Ntl.
R179	K4702-01-00044	Resistor, 10K	1	Moulded Ntl.
R180	K4702-01-00038	Resistor, 3.3K	1	Moulded Ntl.
R181				
R182				
R183				
R184				
R185	K4702-01-00039	Resistor, 3.9K	1	Moulded Ntl.
R186	K4702-01-00032	Resistor, 1K	1	Moulded Ntl.
R187	K4702-01-00039	Resistor, 3.9K	1	Moulded Ntl.
R188	K4702-01-00052	Resistor, 47K	1	Moulded Ntl.
R189	K4702-01-00041	Resistor, 5.6K	1	Moulded Ntl.
R190	K4702-01-00020	Resistor, 100 Ohm	1	Moulded Ntl.
R191	K4734-01-00010	Resistor, Variable 2K	1	Amperex
R192	K4702-01-00056	Resistor, 100K	1	Moulded Ntl.
R193	K4702-01-00036	Resistor, 2.2K	1	Moulded Ntl.
R194	K4702-01-00056	Resistor, 100K	1	Moulded Ntl.
R195	K4702-01-00041	Resistor, 5.6K	1	Moulded Ntl.

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY PER ASSY	MANUFACTURER
PRINTED CIRCUIT BOARD ASSEMBLY (Cont'd)				
R196	K4702-01-00030	Resistor, 680 Ohm	1	Moulded Ntl.
R197	K4702-01-00036	Resistor, 2.2K	1	Moulded Ntl.
R198	K4702-01-00016	Resistor, 47 Ohm	1	Moulded Ntl.
R199	K4702-01-00036	Resistor, 22K	1	Moulded Ntl.
R200	K4702-01-00026	Resistor, 330 Ohm	1	Moulded Ntl.
R201	K4702-01-00024	Resistor, 220 Ohm	1	Moulded Ntl.
R202	K4702-01-00056	Resistor, 100K	1	Moulded Ntl.
R203	K4702-01-00008	Resistor, 10 Ohm	1	Moulded Ntl.
R204				
R205				
R206	K4702-01-00020	Resistor, 100 Ohm	1	Moulded Ntl.
R207	K4702-01-00008	Resistor, 10 Ohm	1	Moulded Ntl.
R208	K4702-01-00056	Resistor, 100K	1	Moulded Ntl.
R209	K4702-01-00028	Resistor, 470 Ohm	1	Moulded Ntl.
X101	K2116-01-00002	Socket, Crystal	1	
X102	K2116-01-00002	Socket, Crystal	1	
X103	K2116-01-00002	Socket, Crystal	1	
X104	K2116-01-00002	Socket, Crystal	1	
X105	K2116-01-00002	Socket, Crystal	1	
X106	K2116-01-00002	Socket, Crystal	1	
Y101	K2305-01-00089	Crystal, Receiver	1	
Y102	K2304-01-00024	Crystal, Transmitter	1	
	PL9016-02-00008	Printed Circuit Board Assembly	1	
	1730-01-00003	Printed Circuit Board	1	

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY PER ASSY	MANUFACTURER
PRINTED CIRCUIT BOARD ASSEMBLY (Cont'd)				
	M2873-50-00501	Screw, Nylon No. 6-32 x 1/4 LG	12	
	M2898-63-31005	Lockwasher, Int Tooth	1	
	K1435-02-00052	Shield, RF	1	
		Alignment Tool	1	
	K2884-63-00009	Standoff, (for alignment tool)	1	
	K5136-01-00006	Clip, (for alignement tool)	1	
	K2806-51-04216	Screw, BD HD No. 4-40 x 1/2 LG	1	
	M2893-51-04204	Nut, No. 4-40	3	
	M2898-63-41002	Lockwasher	2	
	M2884-63-00003	Standoff	2	
	M2806-51-04228	Screw, DB HD No. 4-40 x 7/8 LG	2	
	K3135-01-00200	Tubing, 14-inches	1	
	K6003-01-00004	Wire, Bare No. 20 AWG, 12-inches	1	
TRAY ASSEMBLY				
D1	K4824-01-00001	Diode, 1N91	1	G. E.
J1	K2121-01-00001	Socket, Male (Ext. Bat)	1	Switchcraft
J2	K2109-01-00013	Jack, Phone (Min.)	1	Switchcraft
J3	K2111-01-00004	Socket, Coaxial	1	Dage
LS1	K1310-01-00014	Speaker, 32 Ohms	1	Oaktron
R1	K4735-01-00621	Resistor, Variable, 10K	1	
R2	K4735-01-00620	Resistor, Variable, 10K	1	
R3	K4702-01-00024	Resistor, 1/4W ± 10%, 220 Ohms	1	Moulded Ntl.
R4	K4702-01-00041	Resistor, 1/4W ± 10%, 5.6K	1	Moulded Ntl.
S1	K5125-01-00001	Switch, 4PDT	1	Moulded Ntl.
	PL9016-02-00012	Tray Assembly		

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY PER ASSY	MANUFACTURER
TRAY ASSEMBLY (Cont'd)				
	PL9016-03-00018	Control Plate Assembly	1	
	PL9016-03-00017	Fuse Block Assembly	1	
	PL9016-03-00019	Chassis Assembly	1	
	K2137-01-00005	Cap & Chain	1	Amphenol
	K2806-51-04114	Screw, BD. HD. No. 4-40 x 7/16 LG	2	
	M2893-51-04101	Hex Nut, No. 4-40	2	
	M2898-63-36002	Lockwasher No. 4 Int. Tooth	2	
	M2888-26-12023	Terminal Lug	1	
	M2892-67-12101	Rivet, 3/8 LG	1	
	K3135-01-05200	Sleeving, No. 8, 1-1/8 LG	1	
	K2430-02-00111	Knob, Volume Control	1	
	K2827-67-04104	Set Screw, No. 4-40	1	
	K2137-02-00009	Dummy Connector	1	
	K2806-51-08116	Screw, BD. HD. No. 8-32 x 1/2 LG	1	
	M2893-51-25201	Nut, Hex, 1/4 x 32 x 1/16 THK.	2	
	M2893-51-17202	Nut, Hex, 3/8 x 32 x 1/16 THK.	1	
	M2898-63-36005	Lockwasher, Int. Tooth	2	
	K2537-02-00043	Spring, Speaker Mtg.	1	
	K1450-02-00220	Bracket, Switch Mtg.	1	
	K2806-51-04104	Screw, BD. HD. No. 4-40 x 1/8 LG	1	
	K3123-01-00041	Ring, Speaker Protect	1	
	K2418-02-00053	Label, Battery Polarity	1	
	B2418-02-00052	Label, Tuning Inst. (English)	1	

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY PER ASSY	MANUFACTURER
REPEATER PRINTED CIRCUIT BOARD ASSEMBLY				
C501	M1509-01-01019	Capacitor, Disc Ceramic 0.001 μf	1	R. M. C.
C502	M1528-01-03002	Capacitor, Flat Foil, 0.047 μf	1	Amperex
C503	M1509-01-01042	Capacitor, Disc Ceramic, 0.01 μf	1	R. M. C.
C504	M1509-01-01042	Capacitor, Disc Ceramic, 0.01 μf 25 v	1	R. M. C.
C505	M1509-01-01042	Capacitor, Disc Ceramic, 0.01 μf 25 v	1	R. M. C.
C506	M1509-01-01043	Capacitor, Disc Ceramic, 0.1 μf 25 v	1	R. M. C.
C507	M1509-01-01043	Capacitor, Disc Ceramic, 0.1 μf 25 v	1	R. M. C.
C508	M1509-01-01043	Capacitor, Disc Ceramic, 0.1 μf 25 v	1	R. M. C.
C509	B1515-02-04012	Capacitor, Electrolytic, 4 μf	1	Amperex
C510	B1515-02-04012	Capacitor, Electrolytic, 4 μf	1	Amperex
C511	B1515-02-04012	Capacitor, Electrolytic, 4 μf	1	Amperex
C512	B1515-02-04012	Capacitor, Electrolytic, 4 μf	1	Amperex
C513	B1515-02-04017	Capacitor, Electrolytic, 250 μf	1	Amperex
C515	M1509-01-01042	Capacitor, Disc Ceramic, 0.01 μf	1	R. M. C.
D501	M4805-02-00102	Diode, TS4	1	Diodes, Inc.
D502	M4805-02-00102	Diode, TS4	1	Diodes, Inc.
D503	M4805-02-00102	Diode, TS4	1	Diodes, Inc.
D504	M4805-02-00102	Diode, TS4	1	Diodes, Inc.
J501	K2124-01-00001	Socket, Relay	1	P & Brumfield
L501	1802-02-00051	RF Choke, 2.5 μh	1	P & Brumfield
Q501	K4857-01-00002	Transistor, 2N3693	1	Fairchild
Q502	K4857-01-00002	Transistor, 2N3693	1	Fairchild
Q503	K4857-01-00002	Transistor, 2N3693	1	Fairchild
Q504	K4849-01-00001	Transistor, 2N3638	1	Fairchild

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY PER ASSY	MANUFACTURER
REPEATER PRINTED CIRCUIT BOARD ASSEMBLY (Cont'd)				
Q505	4840-01-00001	Unijunction Transistor, 2N1671	1	G. E.
Q506	4816-01-00001	Silicon Controlled Rect. C6U	1	G. E.
Q507	K4857-01-00002	Transistor, 2N3693	1	Fairchild
Q508	K4859-01-00001	Transistor, 2N3567	1	Fairchild
		Resistors Are 1/4 Watt ± 10% Unless Otherwise Specified.		
R501	K4734-01-00012	Resistor, Variable, 10K Gain	1	Amperex
R502	K4702-01-00037	Resistor, 2.7K	1	Moulded Ntl.
R503	K4734-01-00012	Resistor, Variable, 10K Trip	1	Amperex
R504	K4702-01-00040	Resistor, 4.7K	1	Moulded Ntl.
R505	K4702-01-00050	Resistor, 33K	1	Moulded Ntl.
R506	K4702-01-00028	Resistor, 470 Ohms	1	Moulded Ntl.
R507	K4702-01-00041	Resistor, 5.6K	1	Moulded Ntl.
R508	K4702-01-00050	Resistor, 33K	1	Moulded Ntl.
R509	K4702-01-00046	Resistor, 15K	1	Moulded Ntl.
R510	K4702-02-00160	Resistor, ± 5% 3.6K	1	Moulded Ntl.
R511	K4702-01-00042	Resistor, 6.8K	1	Moulded Ntl.
R512	K4702-01-00036	Resistor, 2.2K	1	Moulded Ntl.
R513	K4702-01-00044	Resistor, 10K	1	Moulded Ntl.
R514	K4702-01-00047	Resistor, 18K	1	Moulded Ntl.
R515	K4702-02-00192	Resistor, ± 5% 75K	1	Moulded Ntl.
R516	K4702-01-00062	Resistor, 330K	1	Moulded Ntl.
R517	K4702-01-00033	Resistor, 1.2K	1	Moulded Ntl.
R518	K4702-01-00032	Resistor, 1K	1	Moulded Ntl.
R519	K4702-01-00036	Resistor, 2.2K	1	Moulded Ntl.

CIRCUIT REFERENCE	PART NO.	DESCRIPTION	QTY PER ASSY	MANUFACTURER
REPEATER PRINTED CIRCUIT BOARD ASSEMBLY (Cont'd)				
R520	K4702-01-00034	Resistor, 1.5K	1	Moulded Ntl.
R521	K4702-01-00046	Resistor, 15K	1	Moulded Ntl.
R522	K4702-01-00036	Resistor, 2.2K	1	Moulded Ntl.
R523	K4734-01-00011	Resistor, Variable, 200K	1	Amperex
R524	K4702-01-00058	Resistor, 150K	1	Moulded Ntl.
R525	K4702-01-00023	Resistor, 180 Ohms	1	Moulded Ntl.
R526	K4702-01-00023	Resistor, 180 Ohms	1	Moulded Ntl.
R527	K4702-01-00024	Resistor, 220 Ohms	1	Moulded Ntl.
R528	K4702-01-00032	Resistor, 1K Ohms	1	Moulded Ntl.
R529	K4702-01-00032	Resistor, 1K Ohms	1	Moulded Ntl.
R531	K4702-01-00032	Resistor, 1K Ohms	1	Moulded Ntl.
	1450-01-00238	Bracket, Relay	1	Moulded Ntl.
	1730-01-00004	Printed Circuit Board	1	Moulded Ntl.
		TWO FREQUENCY KITS		
	9016-02-00017	P. C. Board Assem. Rec.	1	
	9016-02-00018	P. C. Board Assem. Trans.	1	
C20	1509-01-01042	Capacitor .01MFD Disc.	1	R. M. C.
C21	1509-01-01042	Capacitor .01MFD Disc.	1	R. M. C.
C31	1543-01-00001	Capacitor Variable 2-18PF	1	Amperex
D20	4802-01-00001	Diode IN456	1	Sylvania
D21	4802-01-00001	Diode IN456	1	Sylvania
D30	4802-01-00001	Diode IN456	1	Sylvania
D31	4802-01-00001	Diode IN456	1	Sylvania
L20	1806-01-00061	Coil Freq. Adjust	1	Moulded Ntl.
R20	4702-01-00044	Resistor 10K	1	Moulded Ntl.
R21	4702-01-00044	Resistor 10K	1	Moulded Ntl.
R30	4702-01-00044	Resistor 10K	1	Moulded Ntl.
R31	4702-01-00044	Resistor 10K	1	Moulded Ntl.
S30	5101-01-00012	Switch SPST	1	ALCO

SECTION VII

INSTALLATION, OPERATION, AND MAINTENANCE INSTRUCTIONS - ACCESSORY ITEMS

7-1 GENERAL

7-2 This section of the handbook provides instructions for installing, operating, and maintaining three accessory items used with the FM-1 transceiver. These are: the two-frequency conversion kit, the RP-1 back-to-back one-way repeater, and the high gain tactical antenna. The two-frequency conversion kit permits the instrument to operate on two separate frequencies. The RP-1 repeater is designed to increase the normal communication distance of the FM-1. The high gain tactical antenna increases the low-angle transmitted energy of the unit.

7-3 Paragraphs 7-4 through 7-13 describe installation, operation, and maintenance of the two-frequency conversion kit. The RP-1 repeater is covered in paragraphs 7-14 through 7-25, and the description of the tactical antenna starts at paragraph 7-26.

7-4 TWO-FREQUENCY CONVERSION KIT

7-5 DESCRIPTION. The two-frequency conversion kit (Figure 7-1) consists primarily of two diode switching networks actuated from a front panel switch. The networks are built upon two small printed circuit boards (PC601 and PC602) which are plugged into receiver and transmitter crystal sockets X101, X102, X104 and X105. An extra pin at each socket allows a third connection to each board (Sockets X103 and X106) (see Figure 3-1). In the case of the receiver plug-in module, to fit the module to the transceiver printed circuit board it is only necessary to remove the crystal and plug the PC601 module into the FM-1 printed circuit board. The pin spacing is so arranged that the module faces inward. The module is fitted with two crystals. Inductor L20 on the module is used to "pull" the frequency of crystal Y101B, and inductor L105, on the FM-1 printed circuit board, is retained in circuit and used to "pull" the second crystal, Y101A. To install the transmitter two-frequency conversion module it is necessary to cut or remove the jumper wire connected between X105 and X106 adjacent to the transmitter crystal sockets on the FM-1 printed circuit board. The jumper is of plain wire on the top side of the board (see Figure 3-1). The two-frequency module is plugged-in in place of the crystal. A third pin, X106, indexes the module so that the components face inward.

7-6 Capacitor C31 on the module is used to "pull" crystal Y101B, and capacitor C185 on the FM-1 printed circuit board is used to "pull" the second crystal.

7-7 INSTALLATION OF TWO-FREQUENCY SWITCH. After the two modules are in place it is necessary to drill an 0.25-inch hole in the FM-1 front panel. A template is provided as part of the kit in order that the hole may be properly located. The template is placed over the

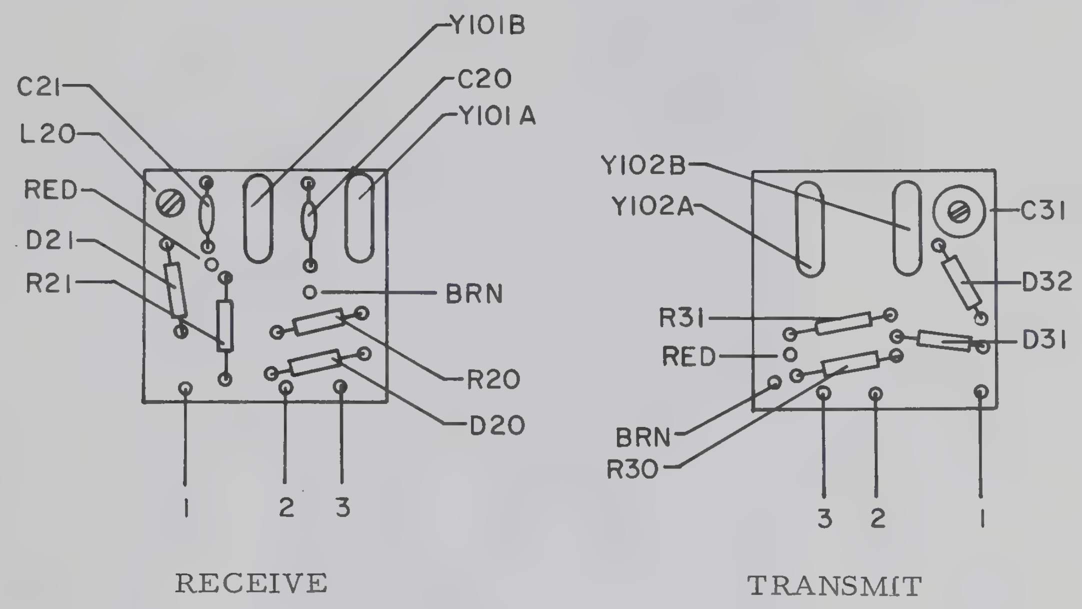


Figure 7-1. Two-Frequency Conversion Kit.
SEE 8-1 FOR SCHEMATIC DIAGRAM

panel and a centering hole made with a center punch. The panel is then drilled. The red wire from switch S30 is connected to the +12 volts on the transceiver side of the ON/OFF switch which is on volume control R1. The FM-1 is now ready for alignment and operation.

7-8 ALIGNMENT OF TWO-FREQUENCY KIT. Alignment of the two-frequency kit is carried out as described in Section III, paragraph 3-15. The frequency switch is placed in one position and the appropriate crystals are aligned to frequency. The switch is then placed at the other frequency and the other set of crystals aligned to frequency.

7-9 OPERATION LIMITATIONS OF TWO-FREQUENCY KIT. Because of the high degree of selectivity obtained in the FM-1 receiver and transmitter circuits, it is necessary to choose frequencies as close as possible to each other. The closer the frequencies the better will be the sensitivity of the receivers and the higher the transmitter output powers. A frequency separation of 600 kc must be considered maximum. Sensitivity and power output may be equalized by adjusting the receiver and transmitter tuned circuits to a position midway between each frequency. This is especially so when the separation is greater.

7-10 OPERATING PRINCIPLES FOR TWO-FREQUENCY KIT. The schematic diagram for the two-frequency circuit is illustrated in Figure 8-1. When frequency selector switch S30 is in the right-hand position, a positive voltage is applied to the anode of D20. Because the cathode

of the diode is connected to ground through L105 when the module is installed, the diode is able to conduct and is therefore in the ON position. Thus, crystal Y101A is connected from the base of Q104, through the link winding on L125 to diode D601 and through L105 to ground. This is a normal oscillating position.

7-11 Meanwhile, diode D21, because it is without positive voltage is not conducting and is OFF, and crystal Y101B is unable to operate. When the switch is thrown to the left-hand position the opposite condition occurs. D21 is ON and D20 is OFF. Y101A is not operating and Y101B is oscillating.

7-12 When the switch is in the right-hand position, positive voltage is applied to diode D32 in the transmitter section causing it to conduct. It is now in the ON position. In effect, crystal Y102B is connected from the base of Q120 through diode D32 to ground. This is a normal oscillating condition. Meanwhile because D31 is without positive voltage it remains OFF and Y102A is inactive. When the switch is placed in the left-hand position, the opposite condition occurs; D31 is ON and D32 is OFF, Y102B is not operating and Y102A is oscillating.

7-13 MAINTENANCE OF TWO-FREQUENCY KIT. Maintenance of the two-frequency kit consists of a VTVM check to assure proper functioning. This is accomplished by the following measurements: when a diode is ON a forward biased voltage across the diode will normally be approximately 0.6 volts; when the diode is in the OFF condition no voltage will be across the diode.

7-14 RP-1 BACK-TO-BACK ONE-WAY REPEATER

7-15 DESCRIPTION. The RP-1 repeater (Figure 7-2) is designed to increase the normal operating communication distance of the FM-1, FM-5 and similar FM equipment. The system is built around two FM-1 transceivers, one of which is used to receive a signal from point A and retransmit the signal through a second FM-1 to point B. When point A has completed transmission, point B may reply, the signal being repeated in the same manner. (See Figure 7-3). In operation, No. 1 FM-1 receives the signal from point A at one frequency (example 150 mc). The signal is then fed via the repeater to No. 2 FM-1 and retransmitted at a different frequency (example 170 mc) to point B. When point B replies the signal is received by No. 1 FM-1 and retransmitted by No. 2 FM-1 to point A. In this example: The receiver at point A would be tuned to 170 mc. The receiver at point B would be tuned to 170 mc. The transmitter at point A would be tuned to 150 mc. The transmitter at point B would be tuned to 150 mc. No. 1 FM-1 would receive only. No. 2 FM-1 would transmit only.

7-16 From the moment a signal is received by the No. 1 FM-1, a timer is actuated in the repeater which causes No. 2 FM-1 to switch off after a period of 3 minutes has elapsed. This circuit prevents a transmitter that has been accidentally left on or an interferring carrier from holding the repeater in the transmit condition. However, when a carrier is removed before the 3 minutes has elapsed, the repeater immediately goes back to the receive condition and the timer resets to zero.

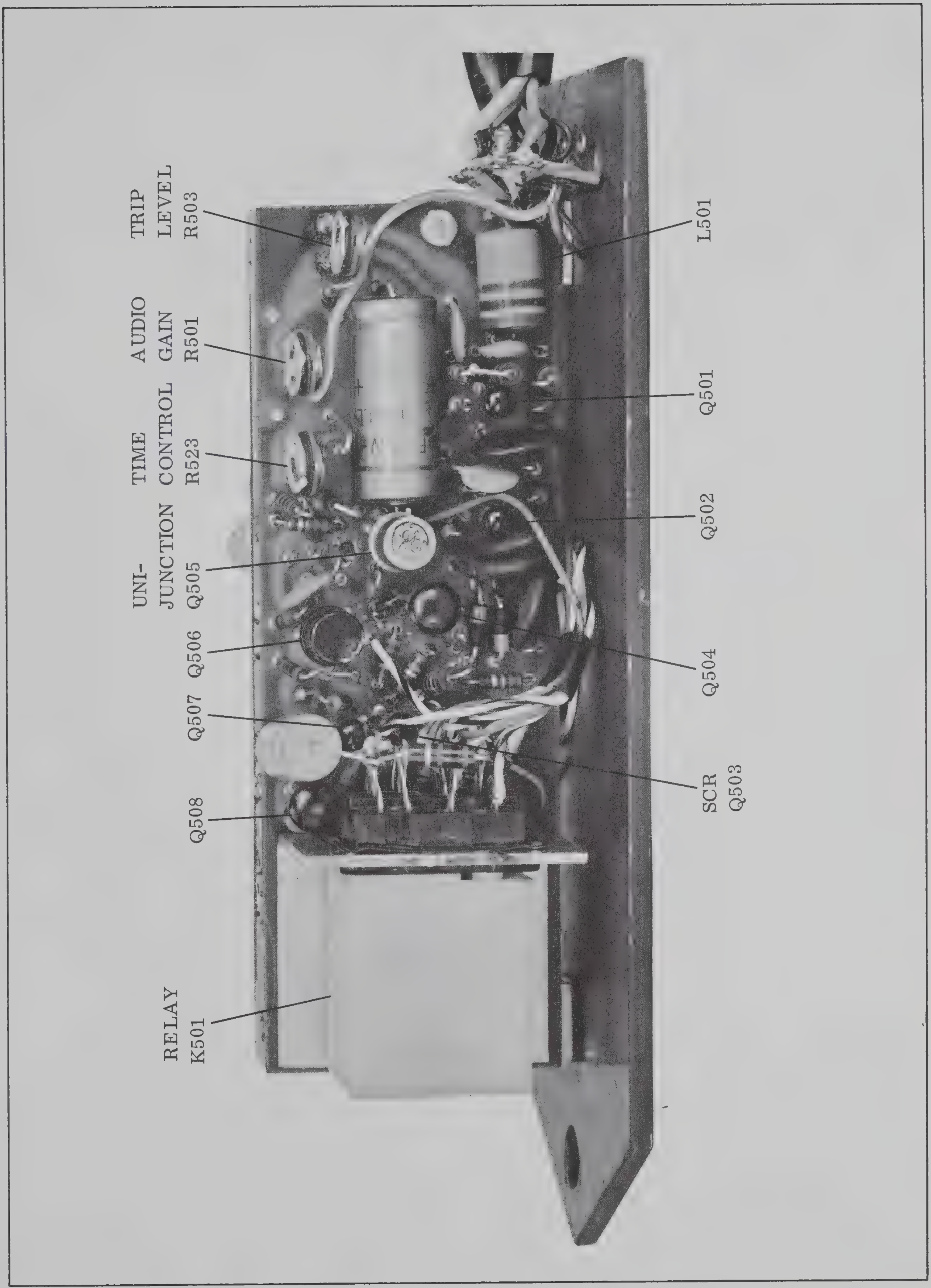


Figure 7-2. RP-1 Back-to-Back One-Way Repeater.

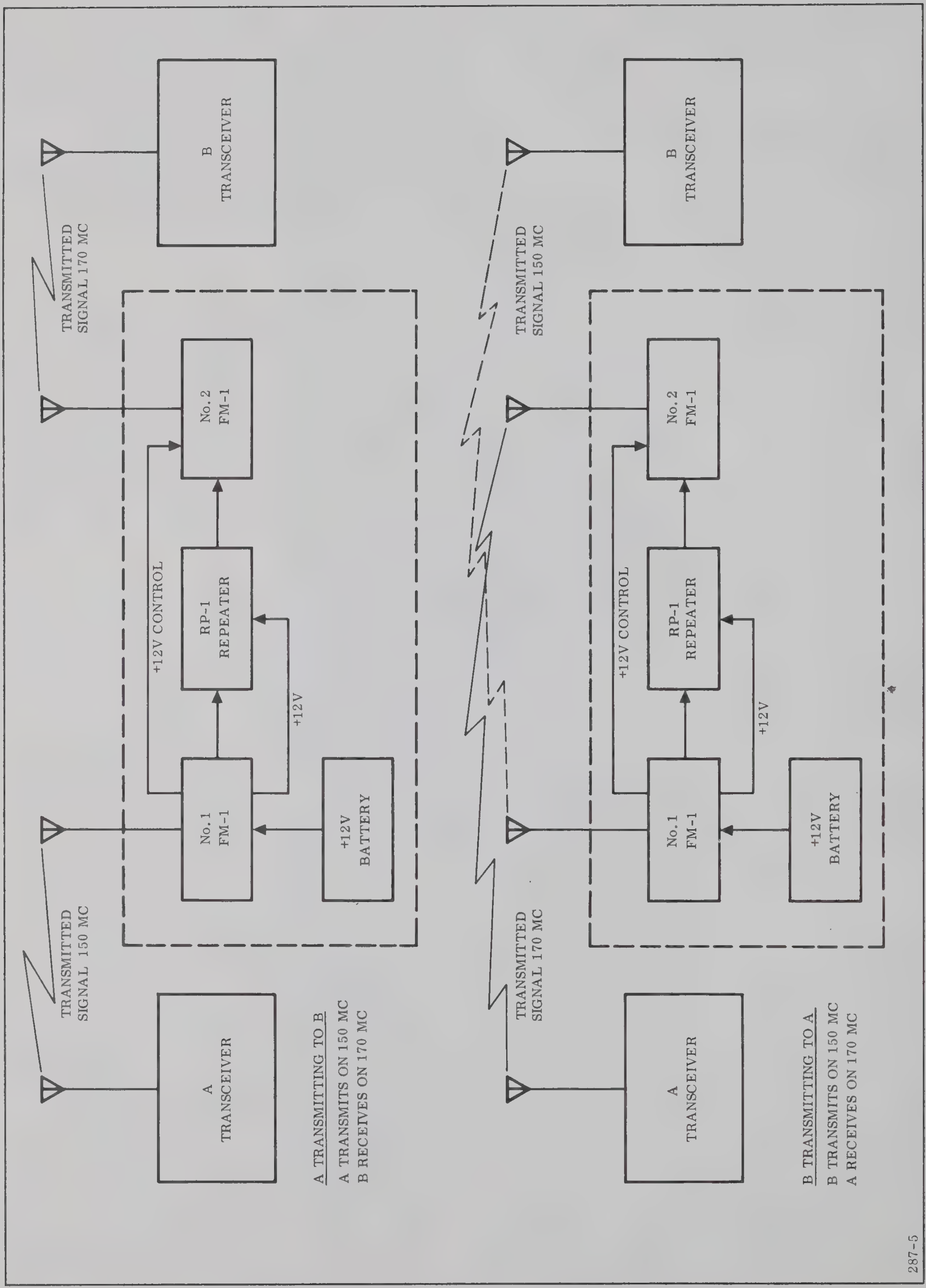


Figure 7-3. RP-1 Repeater Functional Block Diagram.

7-17 INSTALLATION OF RP-1 REPEATER. To operate the two FM-1 transceivers in conjunction with the repeater it is necessary to make modifications to both FM-1 units. A special kit is supplied with the repeater kit to make this conversion. When unpacking the RP-1 repeater equipment, check that the equipment is undamaged and complete. The kit consists of the following:

1. The RP-1 repeater together with the attached three-foot lengths of cables complete with plugs.
2. No. 2 FM-1 adaptor.
3. Cover plate and screws (two sets).
4. For each ten repeaters, one conversion kit consisting of template and punch.

7-18 The two FM-1 units are modified as follows:

1. Remove cases from both FM-1 units.
2. Place the template over the mouthpiece and drill a 3/8-inch diameter hole at the point indicated on the template. The hole will be below the mouthpiece and immediately over the test socket of the printed circuit board.
3. Using the punch supplied with the conversion kit, punch out a hole using the 3/8-inch hole as a guide.
4. Place the template back over the mouthpiece and drill two 1/16-inch diameter holes at the points indicated. These holes are used to hold the cover when the FM-1 is not being used as a repeater. Two thread-cutting screws are provided with the kit for this purpose.
5. Let one FM-1 transceiver be No. 2 FM-1 (transmitter). At the top end of the No. 2 FM-1 remove P101 from socket J4. P101 is the plug at the end of the printed circuit board cable which plugs into the socket on the chassis proper.
6. Insert the adaptor plug provided in the conversion kit in series with plug P101 and socket J4. This adaptor disconnects the antenna from the push-to-talk switch and connects it permanently to the transmitter output. At the same time, the +12 volt supply is disconnected from the receiver. The transmitter +12 volt line is then connected to the test socket. The FM-1 units are now ready for connection to the repeater.

7-19 BATTERY INSTALLATION IN RP-1 REPEATER. Only one battery is necessary to operate the FM-1, the No. 2 FM-1, and the repeater. The battery is connected to the No. 1 FM-1. Either the internal or an external battery may be used. However, the external battery is preferable in view of the extra drain of the repeater unit. Connect batteries to No. 1 FM-1. Connect the repeater cables to the test sockets through the punched holes in the cases of the two FM-1 units. The cable marked "Input From Receiver" connects to the No. 1 FM-1 and the cable marked "Output To Transmitter" connects to the No. 2 FM-2. It is important that the correct cable terminations be ob-

served. At the plug end of the cable marked "Input From Receiver" will be found a small single connection plug P502. This plug must be connected into the small pin jack (J105) on the printed circuit board also accessible through the punched hole in the case of No. 1 FM-1. No. 1 FM-1 is operated in the receive mode only. The transmitter portion of this unit is unused. The receiver portion should be as far removed in frequency as possible from the transmitter of No. 2 FM-1. The receiver portion of No. 2 FM-1 is not used. Frequency separation of the two units should be at least 10 mc. The closer the spacing of the two frequencies the further should be the spacing of the two antennas.

7-20 ANTENNA INSTALLATION FOR RP-1 REPEATER. The importance of obtaining good isolation between the two antennas cannot be too heavily stressed. For best operation the two antennas should be at least 20 feet apart. In some cases the ground plane antenna may be mounted above the other antenna and the ground plane used as a shield between the two dipoles. If feedback occurs between the two transceivers, indicated by squealing noises from the receiver or, in severe cases, by chattering of the relay in the repeater unit, or perhaps lock-up of the transmitter, it is often possible to clear this by moving one antenna further away from the other. A good method for checking this condition is to open the squelch of the No. 1 FM-1. Pull plug P502 from J105 in the No. 1 FM-1. This will turn on the No. 2 FM-1. If a change occurs in the hiss level from the No. 1 FM-1, RF energy from the No. 2 FM-1 is getting into the front end of the No. 1 receiver. The condition can be rectified only by further separation of the antennas or a further separation in frequency. If the hiss level is reduced by the No. 2 FM-1 transmitter, the repeater may not shut off when the incoming signal goes off.

7-21 CONTROL ADJUSTMENTS FOR RP-1 REPEATER. After the repeater is connected to the FM-1 transceivers as described above, turn Trip Level Control R503 counterclockwise until the relay closes. Move back on the control until the relay opens. This is the correct setting. Time control R523 controls the time it takes for the relay to open again after having been closed by an incoming signal, or alternatively, by rotation of Level Control R503. Audio Gain Control R501 is adjusted until proper deviation is obtained from the No. 2 FM-2. The measurement is best made with the aid of a modulation monitor.

7-22 SUCCESSFUL REPEATER OPERATION. In order to successfully repeat the signal from A to B or from B to A it is necessary for the following conditions to exist:

1. Transceiver No. 1 FM-1 must receive a good signal from point A or B.

2. Point A or B must receive a good signal from No. 2 FM-1. The repeater cannot improve a poor signal-to-noise received at No. 1 FM-1.

3. The antenna connected to No. 1 FM-1 must be as far removed as possible from that of No. 2 FM-1. Preferably No. 1 FM-1 should be at one end of the frequency range covered by the FM-1 and FM-5 equipments and No. 2 FM-1 at the other.

SEE SCHEMATIC DIAGRAM 8-9

7-23 THEORY OF OPERATION FOR RP-1 REPEATER. The presence of a signal in an FM receiver using full limiting will cause a reduction in the noise output of the discriminator. This change in noise level, besides being used to operate a receiver squelch is also used to automatically operate a repeater unit. The RP-1 repeater unit obtains its noise voltage via a cable from the receiver portion of the No. 1 FM-1. The noise voltage is amplified by transistors Q501 and Q502. The amplitude of the input signal level is controlled by potentiometer R503. Diodes D501 and D502 rectify the noise produced by Q502. The negative going dc voltage is then applied to the base of dc amplifier Q503, causing this stage to be cut off and the collector voltage almost at the supply voltage potential. This high positive voltage is now applied to the base of PNP amplifier Q504 which causes this stage also to be cut off and the relay to open. The three other stages are inoperative. When a signal causes the noise output from Q502 to fall, the dc output from D501 and D502 also falls, and transistors Q503 and Q504 conduct. Bias voltage is applied to the base of Q503 via R520, Q508 conduct~~or~~s and the relay closes. This applies +12 volts to the No. 2 FM-1, allowing the transmitter portion of this unit to operate. The audio signal from the No. 1 FM-1 is conducted via the cables and the audio gain control R501 to the No. 2 FM-1. When Q504 caused the relay to close, diode gate D504, which had previously been closed, now opens and capacitor C513 begins to discharge through R524 and R523.

7-24 The values of C513 and resistors R524 and R523 are selected so that at the end of three minutes the voltage across the capacitor has fallen to a value sufficient to cause unijunction transistor Q505 to fire, causing a sharp spike to be applied to the silicon-controlled rectifier Q506. Q506 also fires, Q507 conducts, the bias is removed from Q508 because Q507 is now saturated and the relay opens, restoring the FM-1 transceivers to their normal standby position. If the signal is removed before the three minutes are up, the relay opens and the FM-1 transceivers revert to the normal standby position.

7-25 MAINTENANCE OF THE RP-1 REPEATER. Corrective maintenance involves two basic requirements: localization of trouble and its isolation. The localization of trouble is most easily obtained by making use of the voltage charts. A complete voltage chart is provided in Table 7-1.

Table 7-1. Voltage Chart For RP-1 Repeater.

Transistor	Type	Function	Emitter		Base		Collector	
			Relay Position					
			Open	Closed	Open	Closed	Open	Closed
Q501	2N3693	Noise Amp.	0.42	0.36	1.0	0.82	6.25	6.2
Q502	2N3693	Noise Amp.	2.4	2.1	2.56	2.35	6.0	5.6
Q503	2N3693	DC Amp	0	0	-0.8	0.7	12	0.67
Q504	2N3683	Switch	12	12	12	8.8	0	9.5
					Base 1		Base 2	
Q505	2N1671	Timer	0.05	5 Ⓐ	0	9.2	0	0.25
					Gate			
Q506	GEC6U	S. C. R. Switch	0	9.4	0	0	0	0
Q506	GEC6U	S. C. R. Switch	2.8 Ⓑ		2.8 Ⓑ		2.0 Ⓑ	
Q507	2N3693	DC Amp	0	0	0	0	0	6.0
Q507	2N3693	DC Amp	0 Ⓑ		0.75 Ⓑ		0.25 Ⓑ	
Q508	2N3567	Switch	0	0	0	.75	0	0.1

Ⓐ Time = 0 Value. Exponential Delay of Voltage at This Point.
Ⓑ After Time Out and Q506 (SCR) Fired.
Measurements Made with VOM, 0 - 50 μamp.

SECTION VIII

SCHEMATIC DIAGRAMS

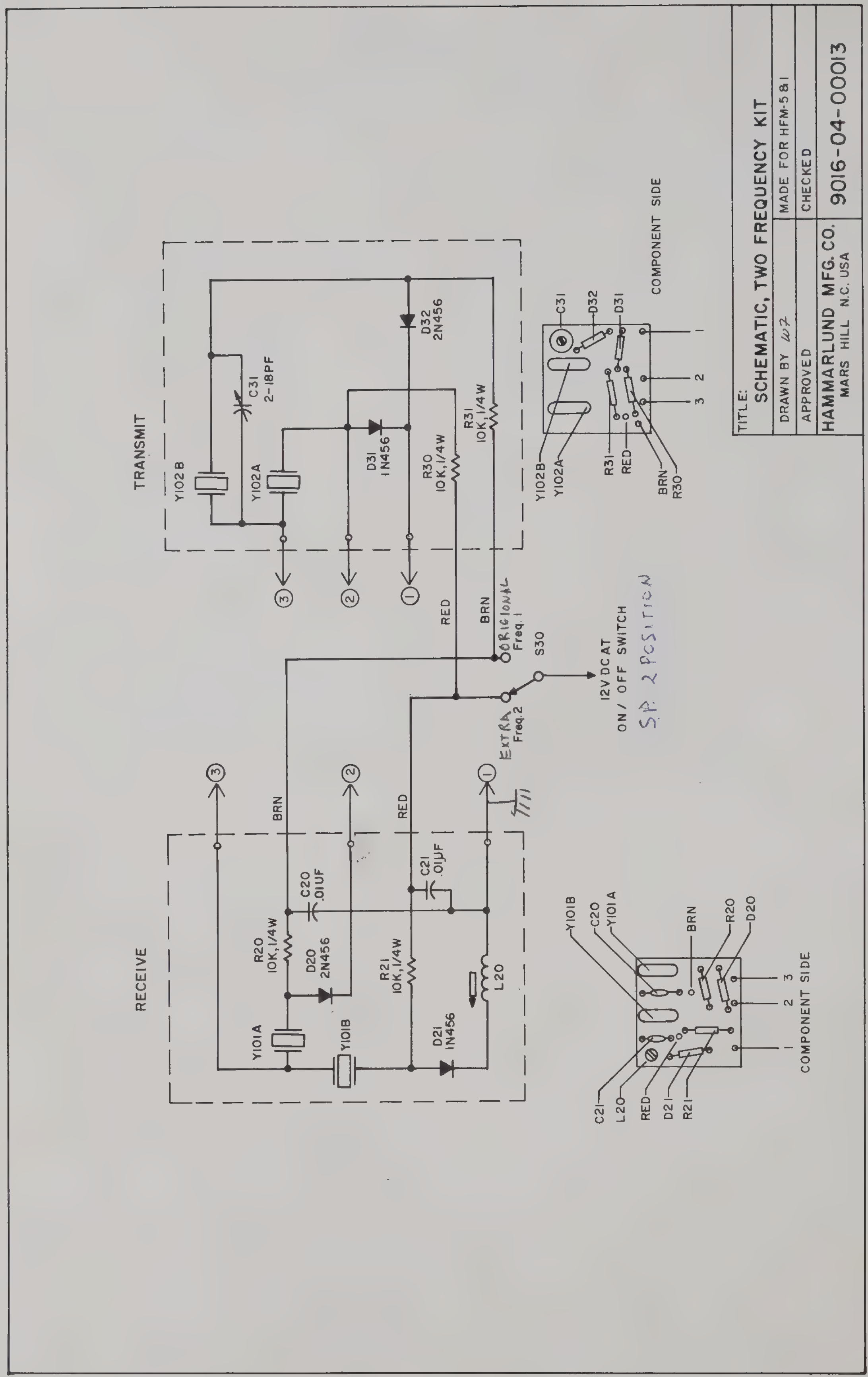
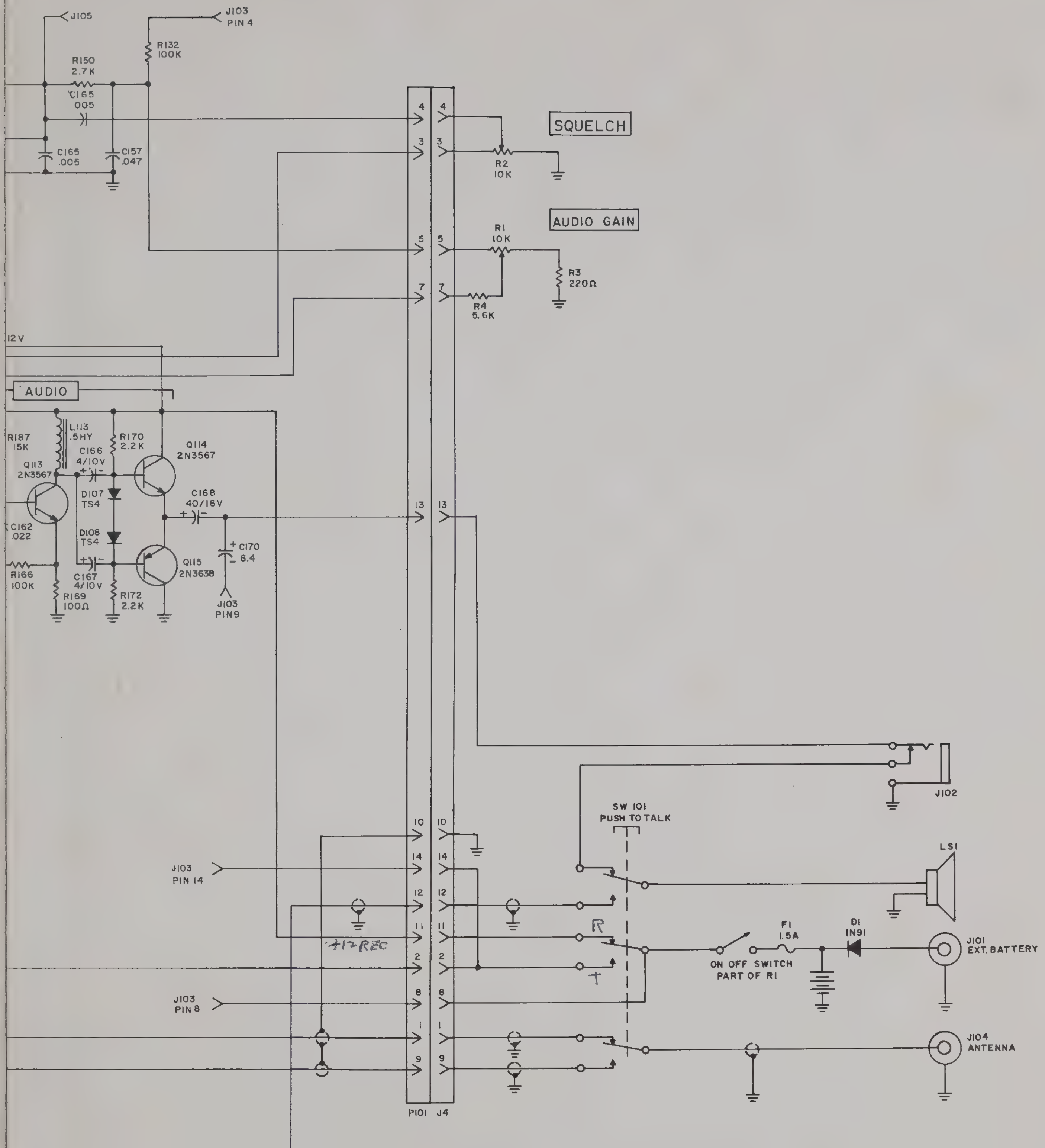


Figure 8-1. Two-Frequency Kit Schematic Diagram



1. ALL CAPACITORS ARE MFD UNLESS OTHERWISE SPECIFIED.

2. ALL RESISTORS ARE $\frac{1}{4}$ WATT $\pm$10% UNLESS OTHERWISE SPECIFIED.

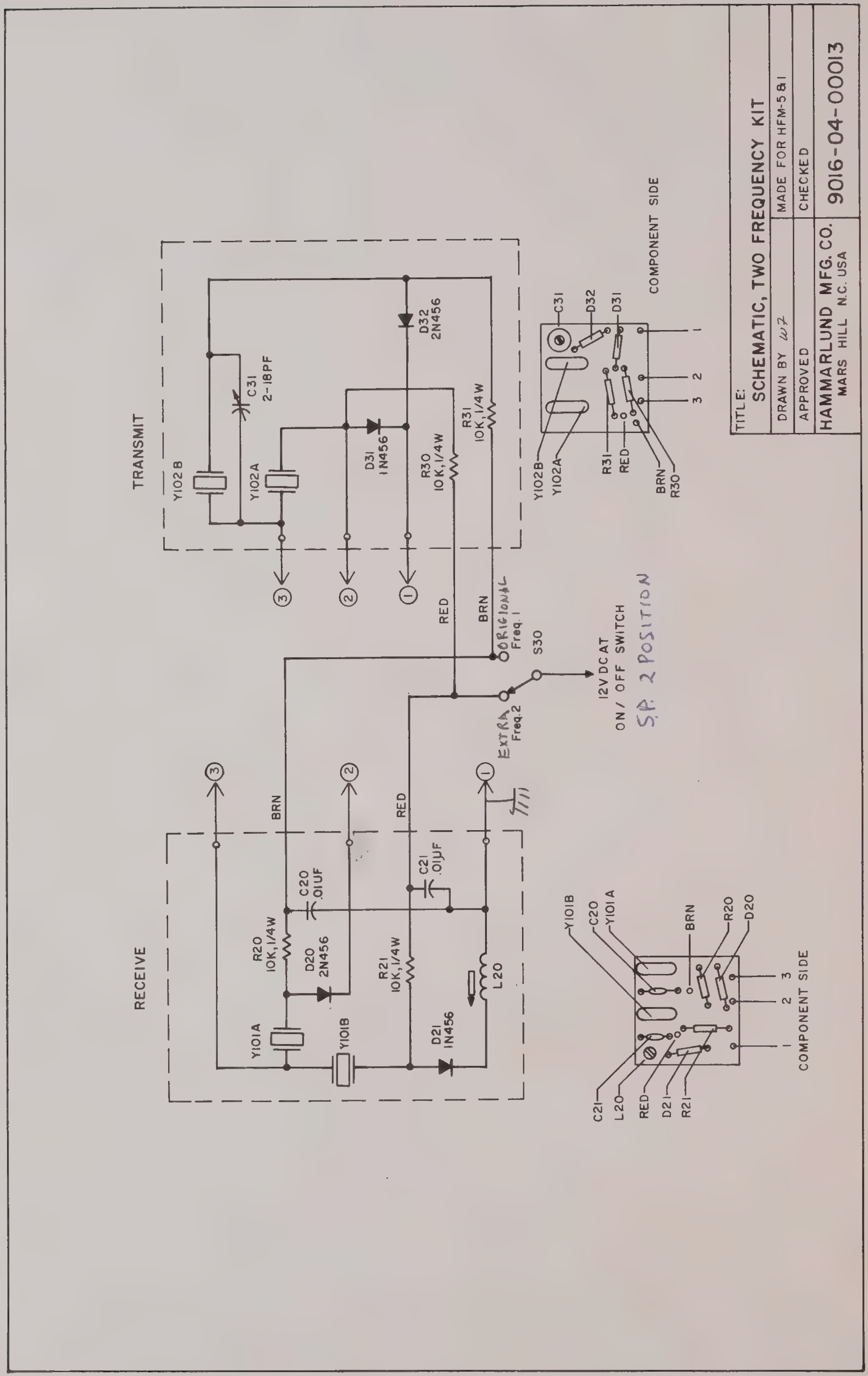


Figure 8-1. Two-Frequency Kit Schematic Diagram

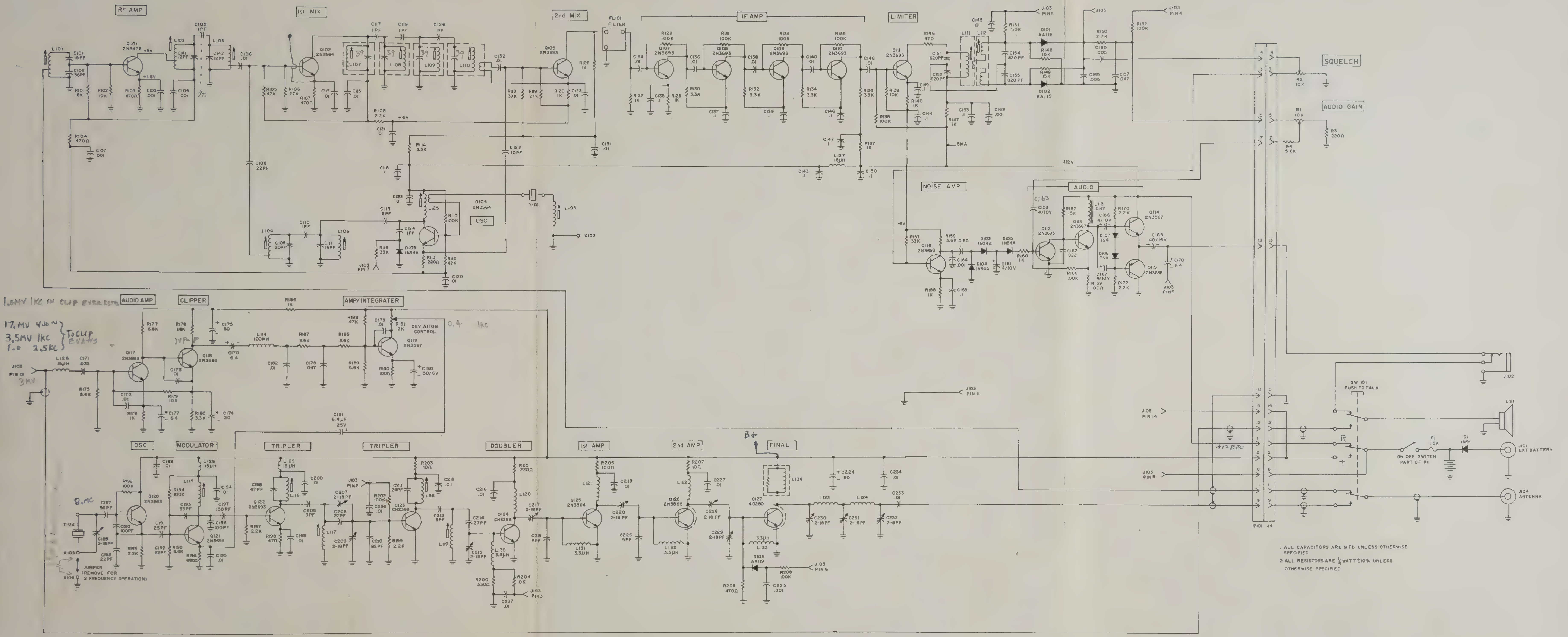


Figure 8-2. Model FM-1 Transceiver Schematic Diagram

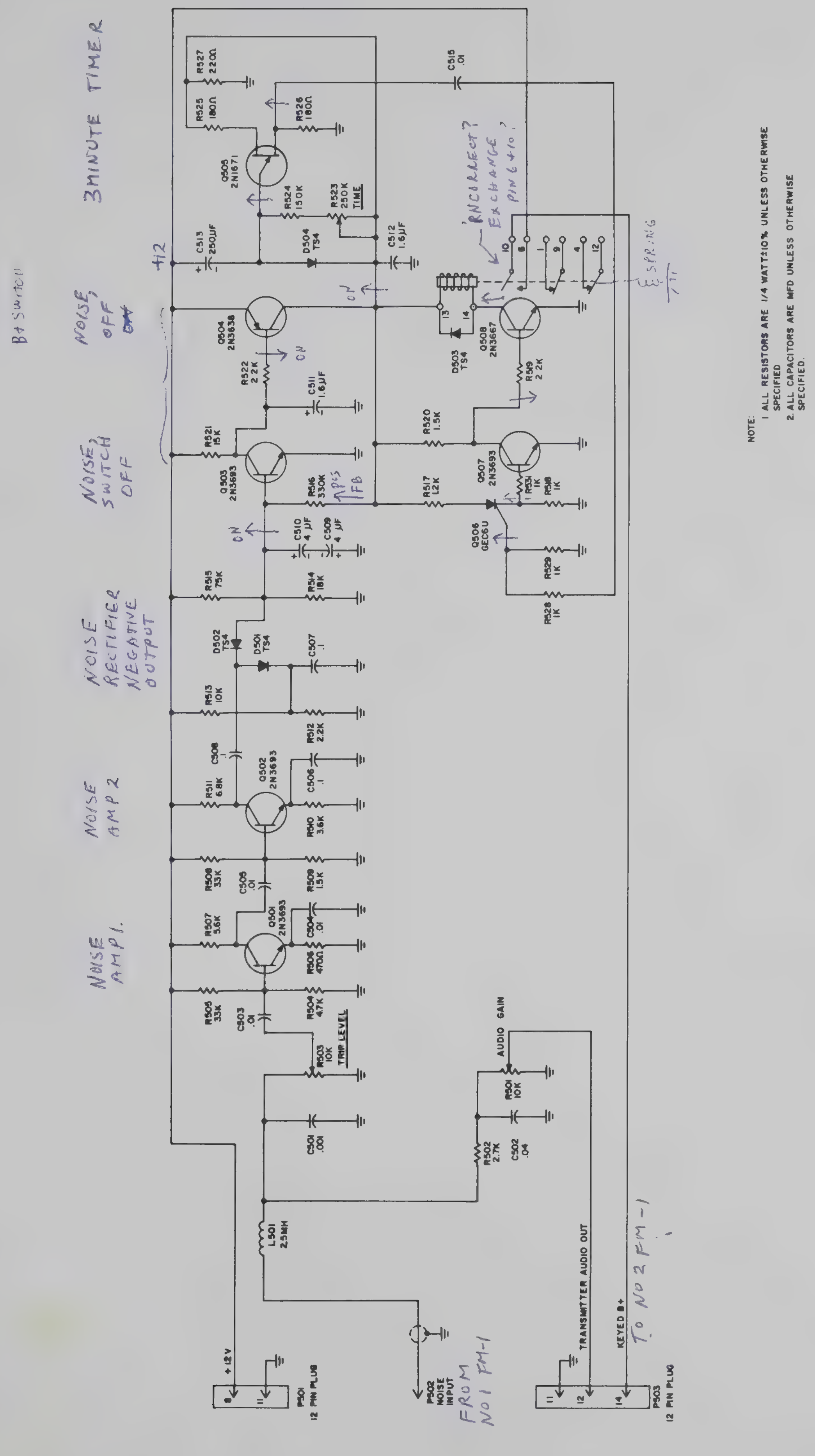


Figure 8-3. Model RP-1 One-Way Repeater Schematic Diagram

ESTABLISHED 1910

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1	Hammarlund Model FM-1	note: I ~~added~~ 2Kc This is 2Kc above the formula.
2	147.450 MHz simplex	
3	Xmit Xtal 8.19166 MHz	Receive Xtal freq 16.335 MHz
4	HC-25/U	HC-25/U
5	Parallel resonance	series resonance
6	32 pF	~~not applicable~~ infinite series capacitance ~~not applicable~~ ~~...~~ (no capacitor in series)
7	fundamental	fundamental
8	non-oven	non-oven
9	± ~~0.005~~ % or (±.0025%)	± ~~0.005~~ % (or ±.0025)
10	markings 8.1916 and T147.450	markings 16.335 and R 147.45

$$F_x = \frac{F_c}{18}$$

35 ohms series resistance

$$F_x = \frac{F_c - 455\,KC}{9} + 2\,KC$$

15 ohm series resist

20
30
32

F_x = crystal freq

F_c = crystal freq